Soviet Acquisition of Militarily Significant Western Technology: An Update

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In recent years, the United States Government has learned of a massive, well-organized campaign by the Soviet Union to acquire Western technology illegally and legally for its weapons and military equipment projects. Each year Moscow receives thousands of pieces of Western equipment and many tens of thousands of unclassified, classified, and proprietary documents as part of this campaign. Virtually every Soviet military research project—well over 4,000 each year in the late 1970s and over 5,000 in the early 1980s—benefits from these technical documents and hardware. The assimilation of Western technology is so broad that the United States and other Western nations are thus subsidizing the Soviet military buildup.

Western products and technology secrets are being systematically acquired by intricately organized, highly effective collection programs specifically targeted to improve Soviet military weapon systems. The Soviet intelligence services—the KGB, the GRU, and their surrogates among the East European services—and Soviet trade and scientific organizations are actively involved in obtaining this technology. Targets include defense contractors, manufacturers, foreign trading firms, academic institutions, and electronic data bases. Only recently has the full extent of illegal Soviet technology collection efforts become known.

The purpose of this paper is to reveal in detail the structure of these Soviet programs, and to give examples of Soviet requirements and successes. Understanding the Soviet effort is a critical first step in protecting Western technology and preventing it from being turned against the West.

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Soviet Acquisition of Militarily Significant Western Technology: An Update

Introduction

Overcoming considerable technological inferiority over the past several decades, the Soviets have built the largest military industrial manufacturing base in the world and a massive research establishment to complement it. Their objective is to achieve military-technical capabilities that are at least equal, if not superior, to those of the West.

Their resource commitment is enormous by any measure; it has enabled them in recent years to narrow the Western lead in nearly all key technological areas, particularly microelectronics. In materials, explosive, and sensor technologies applicable to deployed tactical forces such as tanks, artillery, and antitank and surface-to-air missiles the Soviets' technology level is roughly equal to or slightly better than that of the West. They are the world's leaders in a few significant fields, such as chemical warfare and in some areas of laser research for future "star wars" applications.

Nevertheless, in spite of the several decades of massive investment in indigenous research and development, the prospects are small that the Soviets can reduce their dependence on a large variety of Western products and technology in this decade and the next without allowing the technological gap to widen. The main reasons for this continuing need are endemic to the Soviet system: the lack of adequate incentives, inflexible bureaucratic structures, excessive secrecy, and insularity from the West. Even if there were some major Soviet economic or managerial reforms, *no real lessening of the Soviet dependence on Western innovation is anticipated* as long as the USSR perceives the need for military-technological parity with the West, or the need for superiority.

The impact of this dependence could be even more important in the 1990s than it is today. The USSR has been compelled to follow Western direction in technological change, and thus far it has been able to do this satisfactorily because of a mature technological base. The next decade is less certain for the Soviets, however, because of new technological leadership that the West has supplied them. Their dependence is essentially for *innovation*—where they will continue to look to the West—not for maintaining *adequacy*, which they have achieved in nearly all important military technologies. *But today's adequacy will be tomorrow's obsolescence if technology fails to keep pace.*

In May 1982 the US Congress was given a report [1] identifying a massive and global Soviet program to acquire Western militarily significant technology.[2] That report described the Soviets' successes in supplementing their military research and manufacturing capabilities and in narrowing the technology gap with the West, thereby eroding the technological superiority on which US and Allied security depends.

The identification of this Soviet program led the West to undertake greater efforts in counterintelligence and export control. Since then, it has become even more evident that the magnitude of the Soviets' collection effort and their ability to assimilate collected equipment and technology are far greater than was previously believed.

This update of the 1982 report defines the scope of the Soviet effort. It outlines how the Soviets go about acquiring Western technology and identifies examples of specific technologies they seek. It highlights details and statistics of Soviet successes—much more detail than could be revealed previously. This information was obtained directly by the United States and Allied countries. Understanding the Soviet effort is critical in designing ways to protect Western technology from being acquired and used against Western security interests.

[1] *Soviet Acquisition of Western Technology,* April 1982. Exhibit No. 1. Hearings Before the Permanent Subcommittee on Investigations of the Committee on Governmental Affairs, United States Senate, Ninety-Seventh Congress, Second Session, 4, 5, 6, 11, and 12 May 1982.

[2] Western technology (hardware, documents, and know-how) includes that of Japan as well as other Free World countries.

Soviet Motivations

A basic question is why do Soviet weapon designers and Soviet manufacturers need to copy design concepts embodied in Western equipment and associated documents? In general, Soviet weapons have historically reflected a commitment to functional designs that can be easily manufactured in labor-intensive factories and readily maintained in the field with a minimum of technical skill. There has always been a struggle between Soviet design simplicity and technical complexity. Soviet weapon designers have not had to face the competitive pressures that drive Western designers to press the state of the art.

Building on a mature research sector and on lessons learned from past performances of weapons in battle, the Soviets are placing more of a premium on technically complex systems. Western system and equipment characteristics increasingly are used as yardsticks against which Soviet technical capabilities are judged. Every major civilian or military project is compared with the best Western technology before it is approved for development. Once in development, Soviet standards mandate the comparison of the quality and technical level of hardware, at different design stages, with foreign counterparts.

With their access to many details of Western weapons and dual-use equipment designs and concepts, Soviet designers are, in effect, competing with Western designers. That competition, supported and encouraged by the Soviet leadership, is probably pressuring the military research establishment to pay increasing attention to technically complex systems. Countervailing pressures for design simplicity are being applied by the manufacturing sector, which is less responsive in adapting to technological change. All of these forces indicate continuing Soviet programs to acquire Western military and dual-use hardware and technical data.

Overview of Two Soviet Programs

Since 1982 it has become clearer that the Soviets have two programs to acquire Western hardware and documents:

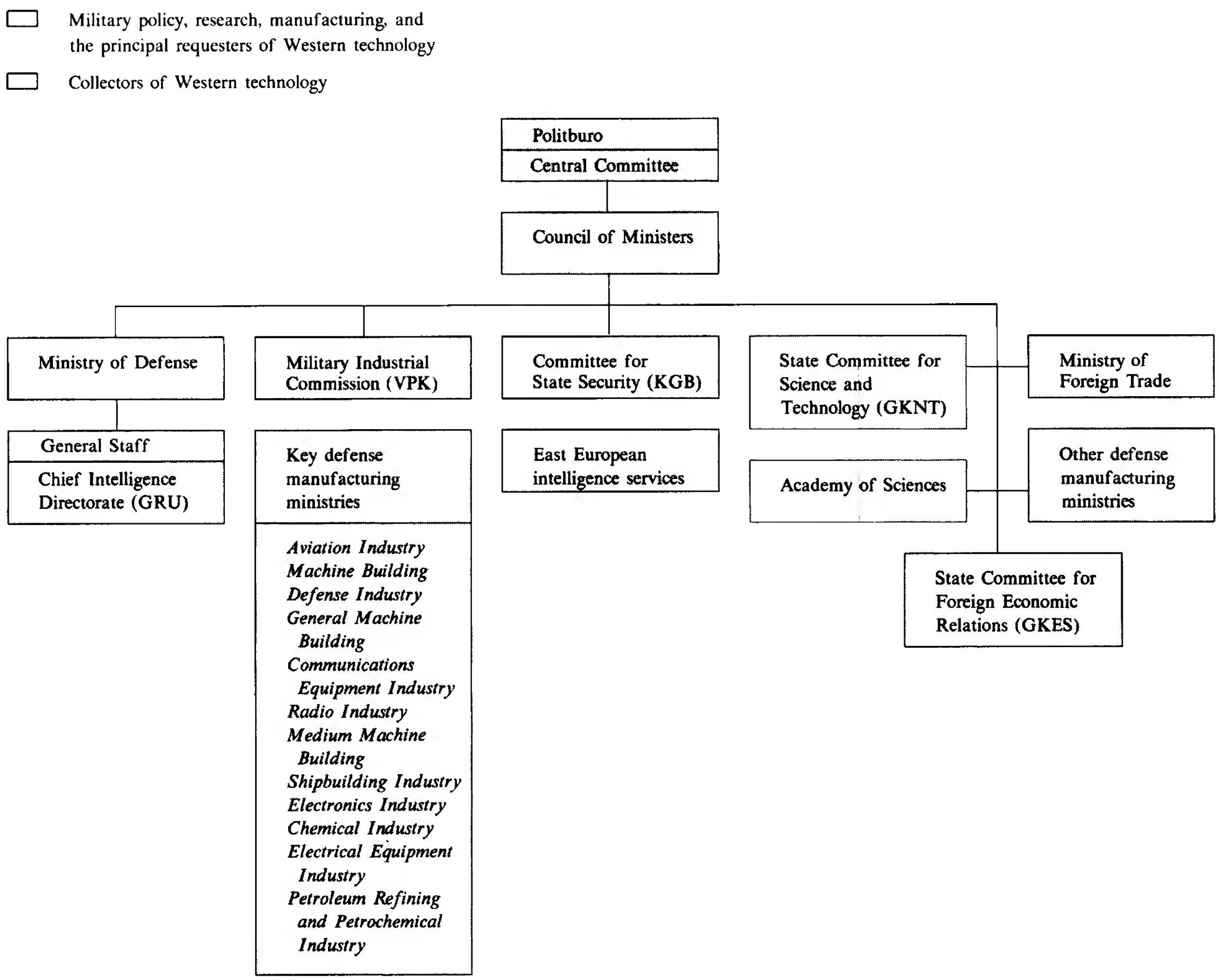
- First, Moscow has a program to raise the technical levels of weapons and military equipment as well as to improve the technical levels of manufacturing processes. This program is managed by the most powerful organization in defense production—the Military Industrial Commission (VPK) of the Presidium of the Council of Ministers (figure 1). Mainly, although not exclusively, through intelligence channels, the VPK seeks one-of-a-kind military and dual-use hardware, blueprints, product samples, and test equipment to improve the technical levels and performance of Soviet weapons, military equipment, and defense manufacturing equipment and reduce any dependency on advanced Western products. This is done in large part by exploiting and adapting design concepts embodied in acquired equipment and associated documents.

- Second, the Ministry of Foreign Trade and Soviet intelligence services administer a trade diversion program to acquire relatively large numbers of dual-use manufacturing and test equipment for direct use in production lines. This program seeks export controlled microelectronics, computer, communications, machining, robotics, diagnostic, and other equipment to increase the throughput of weapon-producing industries.

These two programs, which apparently are administered separately, are the hub of the Soviet effort.

The VPK program is principally, but not exclusively, an industrial security and counterintelligence concern for the West. It involves espionage by hostile intelligence officers, overt collection by Bloc officials, acquisition by scientific exchange program participants, and illegal trade-related activity. The trade diversion

Figure 1
Key Organizations Involved in Managing Military Research and Manufacturing and the Acquisition of Western Technology



The Military Industrial Commission (VPK) coordinates the development of all Soviet weapons as well as the Soviet national-level program to acquire Western technology. The VPK is the most powerful organization in the defense-research establishment, comprising the top executives of the key defense manufacturing ministries (industries). Requests for Western documents and one-of-a-kind hardware from military equipment designers in each of the 12 industries shown above are called requirements (see figure 2).

To satisfy these requirements, the VPK controls a national fund, amounting to some half a billion rubles each year (roughly $1.4 billion in 1980 purchase power equivalents). Once approved by the VPK, requirements are selectively levied among the KGB, the GRU, and at least four other national-level collection agencies, as well as surrogates among the East European intelligence services.

The State Committee for Science and Technology (GKNT) acts as a collector and as the central processor for the national-level program. It also monitors the absorption and assimilation of Western technology by the defense industries.

program principally involves export control and international compliance issues. Characteristics of these programs overlap, further complicating the design of adequate countermeasures:

- Both programs sometimes seek the same products.
- Soviet industrial ministries request technology and equipment through both programs.
- The collection channels overlap and in some cases the same Soviet individuals (intelligence officers and others) are involved in each program.

The VPK Program: Raising the Technical Levels of Weapons and Manufacturing Equipment

The VPK includes the top executives of most of the key Soviet defense manufacturing ministries shown in figure 1. Full VPK membership is given to the Ministers of Aviation, Machine Building (projectiles and explosives), Defense Industry (armor and electro-optics), General Machine Building (strategic missiles and space), Communications Equipment, Radio (radars and large-scale computers), Medium Machine Building (nuclear weapons and high-energy lasers), Shipbuilding, and Electronics. It is a small but powerful group, responsible for centrally overseeing the research, development, and production of all Soviet weapon systems. It coordinates developments between its chief customer, the Ministry of Defense, and the key suppliers, the defense-industrial ministries. As the expediter for weapons development projects, *it is the principal Soviet military instrument for eliminating or circumventing the inefficiencies characteristic of the Soviet economic system.*

As part of its responsibility to enforce schedules and to ensure that technical and performance specifications are met, the VPK translates requests for Western hardware and documents, principally by the design bureaus of 12 industries (figure 1), into lists of collection requirements. In the late 1970s alone about one-half billion rubles (roughly $1.4 billion in 1980 purchase power equivalents) each year was reserved for purchases of one-of-a-kind Western hardware and documents.

Three examples of specific requirements from the VPK lists are shown in figure 2. The first deals with the IBM 370 computer, used by the Soviets as the model for production of their own version, "Ryad," which is a copy of the IBM 370 architecture and functions. The second deals with a cruise missile computer. The VPK apparently assigned it a high priority because of major efforts under way at that time to develop long-range strategic cruise missiles, which require large-capacity digital memories for onboard navigation. The Soviets historically have had reliability and other problems in developing such computers. The third example is a US Fairchild Instrument Corporation/Xincom semiconductor memory tester. It is a good example of the one-of-a-kind dual-use product requested and acquired through the VPK program. Design concepts embodied in the hardware and associated documentation of the tester were copied to develop a Soviet counterpart. The original tester also could be used to help copy or reverse-engineer Western integrated circuits.

Requirements for documents alone can command amounts as considerable as hardware; examples include over 50,000 rubles (roughly $140,000 in 1980 purchase power equivalents) for documents on the US shuttle orbiter control system and over 50,000 rubles for high-energy laser developments. Over 200,000 rubles ($560,000) was approved for acquiring selected research documents on US antimissile defense concepts.

Each year the VPK publishes a report based on the evaluation of the individual ministries. It includes aggregate statistics on numbers of technical documents and samples (hardware) obtained, gross ruble savings, and the numbers and priority of requirements satisfied. This report is sent to the Chairman of the Presidium of the Council of Ministers and to the Central Committee of the Communist Party. Copies also are sent to headquarters elements of the collection organizations.

Figure 2
Examples of VPK Requirements, Mid 1970s - Early 1980s

Mid 1970s

Requester (responsible for producing mainframe computers)	1. Ministry of the Radio Industry
Desired technology	2. Technical documentation on IBM 370 computer models 145, 158, 168 and operating system data, not earlier than 1974. Information about new IBM projects.
Organization charged with collection	3. KGB
Origin or location of technology	4. US: Documents from the IBM firm.

Late 1970s

Joint requirement. Priority code A-I indicates technology needed for potential solutions of a problem in producing a <u>future</u> weapon system	1. Ministries of Aviation, Communications Equipment, and Electronics Industries, A-I, Most Critical
Desired technology	2. Electronic components and programing devices for cruise missile digital computer memory. Samples and documents desired.
Maximum funds allocated for collection of this item	3. 170,000 rubles
Organization charged with collection	4. KGB

Early 1980s

Code B-I indicates substantial reduction in time and expenditure in production of <u>new</u> weapons	1. Ministry of the Electronics Industry, B-I
Desired technology	2. Xincom monitoring and metering equipment for static and functional testing of semiconductor memory units. Sample and documents desired.
Maximum funds allocated for collection of this item	3. 4,500,000 rubles
A nonintelligence organization also charged with assisting collection	4. Ministry of Foreign Trade, KGB

The mid-1970s VPK requirement shown above targets IBM equipment for Soviet military research and development. The Soviets copied the architecture of the IBM 360 and 370 systems to develop their Ryad series of computers. The late 1970s requirement is a very high priority for three reasons: it is identified as "most critical"; it is needed to solve problems in producing a *future* weapon system; and *three* ministries would benefit technically, economically, and jointly from its acquisition. The early 1980s requirement, for a Fairchild/Xincom semiconductor memory test system, is a perfect example of the one-of-a-kind dual-use product (sample) and associated documentation requested for copying as well as for volume purchases for direct use in production lines. This tester was in fact acquired, and design concepts were copied, saving several hundred man-years of Soviet developmental effort.

Soviet requirement data also include the firms and sometimes the names of persons who have the desired hardware and documents. Some 3,000 to 5,000 new, amended, and reapproved requirements for hardware, documents, or both are now issued by the Soviets each year.

Table 1
Summary of Results of the VPK Program, Late 1970s and Early 1980s

- An average of over 5,000 Soviet military equipment and weapon system research projects per year in the early 1980s benefited from Western hardware and technical documents. Over half of these projects were in the electronics and the armor and electro-optics industries.
- Innovation, new concepts, new directions, higher technical levels of research, accelerated development of more advanced weapons, and the avoidance of major pitfalls are some of the key benefits to Soviet military scientific research projects.
- In the early 1980s more than 3,500 requirements were levied each year for specific Western hardware, documents, or both, with roughly one-third satisfied each year; the other two-thirds still targeted.
- Some half a billion rubles are maintained each year for potential collections against these requirements (roughly $1.4 billion in 1980 purchase power equivalents).
- During the 10th Five-Year Plan (1976-80), over 3,500 requirements were fully satisfied worldwide—roughly 60 to 70 percent of these being fulfilled by the Soviet intelligence services (the KGB and the GRU) and surrogates among the East European intelligence services. Requirements fully satisfied during the 11th Five-Year Plan will exceed 5,000.
- Of the 3,500 satisfied requirements approximately 5 to 10 percent were judged by the Soviets as the most significant to military research projects. The Soviet intelligence services and surrogates among the East European services fulfilled about 90 percent of these most significant requirements each year.
- About half of all VPK requirements fulfilled in the 10th Five-Year Plan (1976-80) and thus far in the 11th Five-Year Plan (1981-85) were for two industries: electronics and communications equipment.
- About 60 percent of that portion of document and hardware acquisitions considered to be the most significant to the Soviets was of US origin, although not necessarily collected in the United States.
- About 70 percent of the documents and hardware acquired in the 10th and so far in the 11th Five-Year Plans, which were judged by the Soviets to be the most significant to their military research projects, probably were export controlled, embargoed, classified, or under some control by Western governments.
- About 50 percent of the 6,000 to 10,000 pieces of hardware acquired annually and 20 percent of the 100,000 documents acquired annually are used by the Soviets in transferring Western technology into their military research projects.
- In the late 1970s about 700 embargoed dual-use manufacturing, diagnostic instrumentation, and other dual-use products were acquired each year for copying embodied designs, reverse-engineering, and probably for selected direct use as key equipment in Soviet military production lines.
- From 1976 to 1980 the greatest savings in research project costs, almost one-half billion rubles (the 1980 dollar cost of equivalent research activity would be $800 million), were realized by two ministries—the Ministry of the Defense Industry (armor and electro-optics) and the Ministry of the Aviation Industry. The Soviet manpower equivalence of these savings alone translates roughly into over 100,000 man-years of scientific research. These savings, however, may be biased. The ruble figures probably reflect operating costs—salaries, bonuses, and sometimes savings in elimination of, for example, test range activity, but not capital costs. Although Soviet managers generally tend to inflate savings to enhance their role, the savings estimated in the VPK program appear to be conservative.

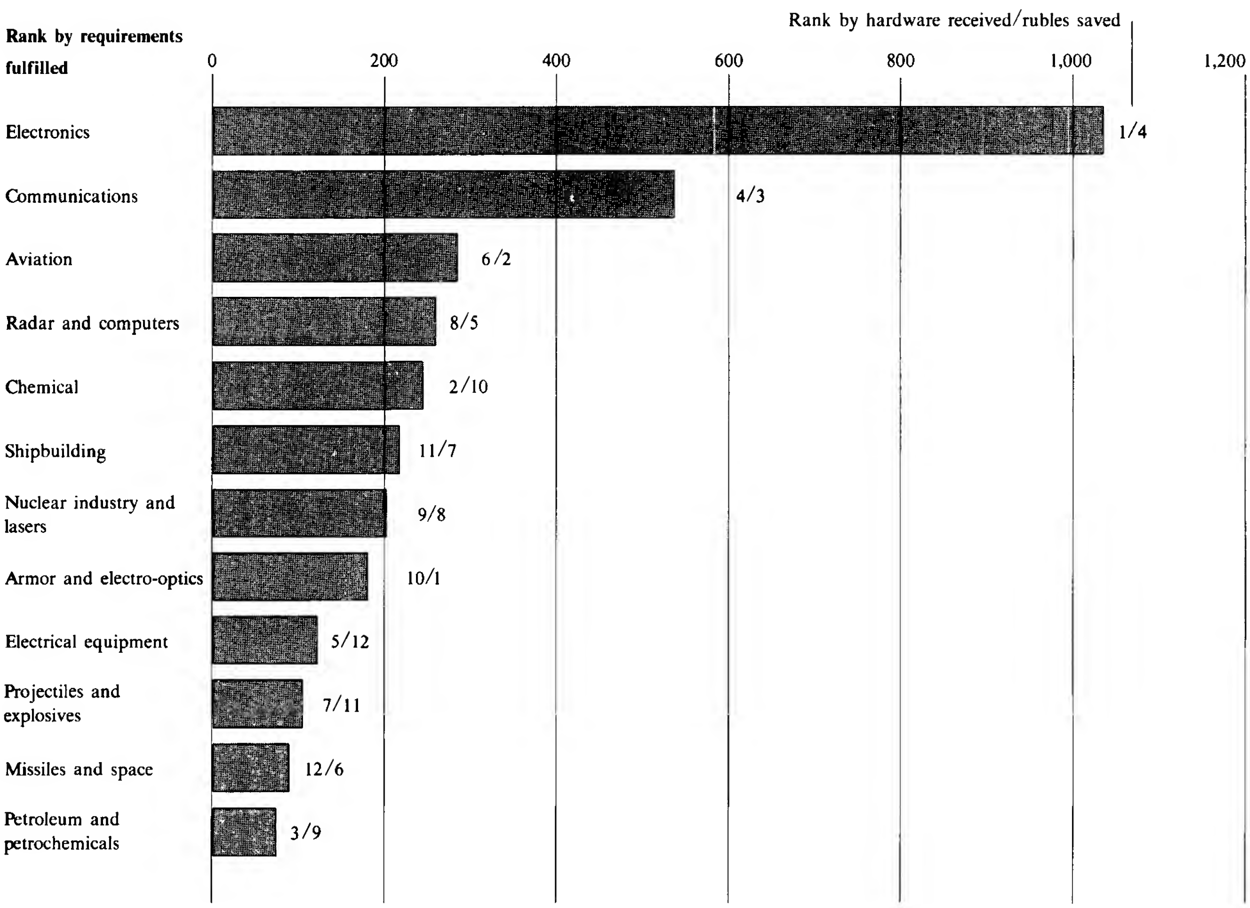
Successes and Benefits

The VPK program is a Soviet success story (table 1). Over 3,500 specific collection requirements for hardware and documents were satisfied for the 12 industrial ministries for just the 10th Five-Year Plan (1976-80). About 50 percent of more than 30,000 pieces of Western one-of-a-kind military and dual-use hardware and about 20 percent of over 400,000 technical documents collected worldwide in response to these requirements were used to improve the technical performance of very large numbers of Soviet military equipment and weapon systems. The benefits and distribution by industry of the fulfilled requirements are shown in figure 3.

According to the Soviets, about one-third of the VPK requirements are totally or partially fulfilled annually, strongly suggesting that Western industrial security, counterintelligence, export controls, and other efforts do have an effect. But each year the number of VPK requirements grows by about 15 percent. This is a strong indication that the expanding Soviet military industrial program continues to rely on Western technical solutions and advances. It also indicates increased collection success and user expectation.

Figure 3
Rank Ordering of Soviet Industries by VPK Requirements Fulfilled, by Rubles Saved, and by Hardware Received, 1976-80

Number of requirements for Western documents, hardware, or both



About 50 percent of the VPK requirements that were fulfilled during the 10th Five-Year Plan for Western hardware and documents were satisfied on behalf of two defense industries—electronics and communications. These are key areas where the Soviets' need for militarily significant technology and the West's need for better controls are greatest.

The four industries receiving the most Western military hardware and dual-use products were electronics (over 6,000 pieces of equipment, a large percentage involving microelectronics), chemical (almost 4,000 pieces), petroleum/petrochemicals (over 1,500), and communications (over 1,500), ranked in that order.

The top four industries saving the most rubles in research project development costs in terms of manpower and other resources were the armor and electro-optics industry (almost 20 percent of the 1.4 billion rubles saved in research project costs) and the aviation, communications, and electronics industries. These four industries consistently appear to be the Soviet leaders in requesting, absorbing, and generally getting the most use out of Western hardware and documents. In some cases, such as in the armor area, the Soviets are using Western technology not to catch up, but to enhance a capability that already is equal to or better than that of the West.

Five Years Gained in Developing the Next Generation of Fire-Control Radars for Soviet Fighter Aircraft

The Soviets estimated that by using documentation on the US F-18 fighter their aviation and radar industries saved some five years of development time and 35 million rubles (the 1980 dollar cost of equivalent research activity would be $55 million) in project manpower and other developmental costs. The manpower portion of these savings probably represents over a thousand man-years of scientific research effort and one of the most successful individual exploitations ever of Western technology.

The documentation on the F-18 fire-control radar served as the technical basis for new lookdown/shootdown engagement radars for the latest generation of Soviet fighters. US methods of component design, fast-Fourier-transform algorithms, terrain mapping functions, and real-time resolution-enhancement techniques were cited as key elements incorporated into the Soviet counterpart.

Moreover, F-18 and F-14 documentation served as the impetus for two long-term research projects to design from scratch a new radar-guided air-to-air missile system. The documentation also was instrumental in formulating concrete specifications to develop new Soviet airborne radar countermeasures equipment against the F-18 and F-14.

Significant acquisitions of Western technology include documents on fire-control radars for the F-14, F-15, and F-18 and documents on US ballistic missile defense concepts (table 2). In terms of broad defense programs, Soviet strategic missiles, air defense, tactical forces, and weapons manufacturing capabilities have benefited the most from the VPK program. The annex has several hundred examples of specific Soviet weapons and military equipment benefiting from Western technology.

Western technology collected each year in the late 1970s and early 1980s aided Soviet military industries principally in four ways. Ranked by priority, the VPK program:

- Redirected Soviet technical approaches in about a hundred projects each year for ongoing weapon systems and key military equipment, or resulted in the improvement of the weapons manufacturing processes.

- Initiated several hundred new short-term and long-term research projects each year on technical topics that had not been under consideration.

- Raised the technical levels of several thousand developmental projects each year involving military equipment, manufacturing, or design procedures.

- Eliminated or shortened phases of more than a thousand military research projects each year. This contributed to a substantial reduction—in a number of cases, two to three years—in time needed to produce more technically advanced weapons and military equipment.

The benefits vary from project to project. Western technology has assisted the Soviets in reducing their weapon acquisition cycle by up to two years for research projects in an advanced status. Acquisition of Western documents, for example, helped the Soviets cut by two years the time spent on researching a new generation of fuzes for munitions with a large kill radius and for self-aiming aviation cluster munitions. For projects in an earlier stage of research, the cycle can be reduced as much as five years. This considerably shrinks overall research time, reduces the amount of resources devoted to weapon system research, and allows diversion of those resources to other Soviet military research projects.

A wide range of Soviet data demonstrates that benefits to military research projects have increased significantly from the late 1970s to the early 1980s (figure 4) and have applied to thousands of research projects in all key defense industries. Measured in rubles, the

Table 2
Selected Worldwide Soviet Acquisitions, Military Applications, and Collectors of Western Documents, Military Hardware, and Dual-Use Products

Western Technology Acquired	Soviet Application/Improvement	Collector
Strategic Missiles		
Documents on Cruise Missiles Using Radar Terrain Maps	Cruise Missile Guidance	KGB, GRU
Documents on Heat Shielding Material for Reentry Vehicles	Ballistic Missile Warheads	KGB, GRU
Documents on Ballistic Missile Defense Concepts	Future Ballistic Missile Defense	KGB, GRU
Air Defense		
F-14, F-15, F-18 Documents on Fire-Control Radars	Four Soviet Fighter Aircraft	KGB, GRU
US Phoenix Missile Documents	Semiactive Air-to-Air Missile	KGB
Infrared Radiometer	Reduced Infrared Signature Aircraft	KGB
Fiber-Optics Systems	Aircraft and Missile Onboard Communication Systems	GRU
Air-to-Air Missile Documents	New Air-to-Air Missile	GRU
General Purpose Naval And Antisubmarine Warfare		
Aircraft Carrier Steam Catapult Design Documents	Aircraft Launching System for New Aircraft Carrier	GRU
US MK 48 Torpedo Documents	Antisubmarine Torpedo	GRU
Gamma Radiation Radiometer	Nuclear Submarine Wake-Detection Trailing System	GRU
Acoustic Spectrum Analyzer	Submarine Quieting	GRU
Powerful Acoustical Vibrator	Submarine and Ship Sonars	GKNT, GKES, Academy of Sciences
Space and Antisatellite Weapons		
Documents on Systems and Heat Shielding of the US Space Shuttle	Reusable Space System	KGB
Transit Naval Navigation Hardware	First-Generation Space-Based Naval Radionavigation System	GRU
US NAVSTAR Navigation System Documents	Digital Signal Processing for Counterpart Satellite System	Others
High-Energy Chemical Laser Documents	Space-Based Laser Weapon	KGB
System 101 Processing Equipment	Digital Processing and Video for Space-Based Reconnaissance; Missile, Bomb, and Remotely Piloted Vehicle Command Guidance	Others
Tactical Forces		
International Radar Conference Documents	Synthetic Aperture Radar for Aircraft Detection	GRU
Ground Support Equipment for US TOW Anti-tank Guided Missile	Countermeasure System	GRU
US Copperhead Laser-Guided Artillery Documents	New Laser-Guided Artillery Shell	GRU
Laser-Guided Missile Documents	Portable Antiaircraft System	KGB
Infrared Imaging Subsystem Designs	Fire-Control System of Future Tank	KGB
Millimeter Radar Documents	Antitank Missile	GRU
Pressure Measuring Instruments and Documents	Advanced Modeling for New Artillery Projectiles	KGB, GRU

Table 2
Selected Worldwide Soviet Acquisitions, Military Applications, and Collectors of Western Documents, Military Hardware, and Dual-Use Products (continued)

Western Technology Acquired	Soviet Application/Improvement	Collector
Manufacturing and Technology		
Kevlar 49 Fiber Documents for Missiles	Improved Missile Development	KGB, GRU
Complete Set of Manufacturing Equipment for Printed Circuit Boards	Copied for 11 Production Assembly Lines for Strategic Missile, Armor and Electro-Optics, and Radar Industries	Ministry of Foreign Trade
DTS-70 Printed Circuit Board Testing System	Military Microelectronic Production System	KGB
Fiberglass Manufacturing Technology	High-Pressure Airtanks for Submarines	KGB, GRU, Ministry of Foreign Trade
Computer Disk Memory Systems	Military Ryad Series Disk Drives	KGB
Bubble Memory Technology	Tactical Missile Onboard Memories	Others
Technical Documents on Tests of Cold-Rolled Steel	Improved Structural Protection of Warships	KGB
High-Accuracy Three-Dimension Coordinate Measuring Machine	Copied for Several Industries	Ministry of Foreign Trade, GKNT, GKES, Academy of Sciences

savings doubled between 1976 and 1980 (figure 5) and still are expanding in the 11th Five-Year Plan. The statistics on benefits also point to a massive diffusion of Western technology into Soviet military equipment and weapons. Figure 6 shows how the more than 5,000 military research projects benefiting in the early 1980s were distributed by industry. According to these rough indicators, the electronics, armor and electro-optics, and aviation industries are benefiting the most from Western technology.

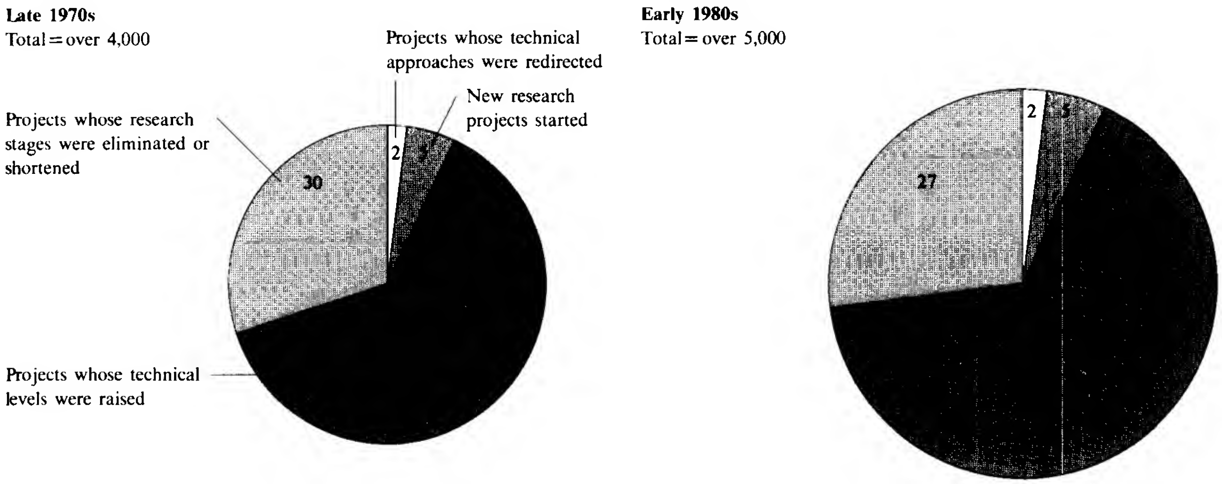
Overall, the acquisition of Western technology permits the Soviets to field more sophisticated, versatile, and effective weapons. The basic time for fielding these advanced Soviet weapons, though, remains about the same. It also provides new military capabilities and allows additional resources to be used for the development of additional advanced weapons concepts. The acquisitions also serve to lighten somewhat the burden of continuing growth in Soviet research and defense spending.

Soviet copying and reverse-engineering of Western military and dual-use equipment are major characteristics of the VPK program. Indeed, the majority of VPK requirements for "technology" appears to be for hardware only. In the late 1970s alone, the Soviets acquired about 700 embargoed one-of-a-kind dual-use products each year principally in the area of manufacturing, inspection, instrumentation and test equipment, including key microelectronics production and test equipment. These products were used for making Soviet counterparts or possibly were for use as key manufacturing or test equipment that completed process lines. Examples included computer-controlled integrated circuit testers, aircraft engine vibration control systems, and narrow-band analyzers for submarine quieting.

These practices indicate Soviet deficiencies are in the design, testing, and integration of technologically advanced military systems, not in basic research and applied science. They fall short in the engineering of a

Figure 4
Technical and Time Benefits to Thousands of Soviet Military Research Projects From Western Technology

Percent



The benefits to the Soviet military research establishment from acquisitions of Western technology are far greater than previously believed. Virtually every Soviet long- and short-term research project for military systems—well over 4,000 in the late 1970s and well over 5,000 in the early 1980s—is benefiting from the documents and hardware of at least a dozen Western countries. (See figure 6 for a breakout of how these projects were distributed by industry.)

Projects in the VPK program are divided into the four major categories shown above. Projects with redirected technical approaches and new projects represent the most significant benefits through adoption of innovations and new directions for military systems. Major pitfalls are thus avoided. Projects whose technical levels were raised and those whose stages were eliminated or shortened represent improvements in the military state of the art of the Soviet Union and an acceleration in the time when more advanced subsystems are ready for new and future weapons.

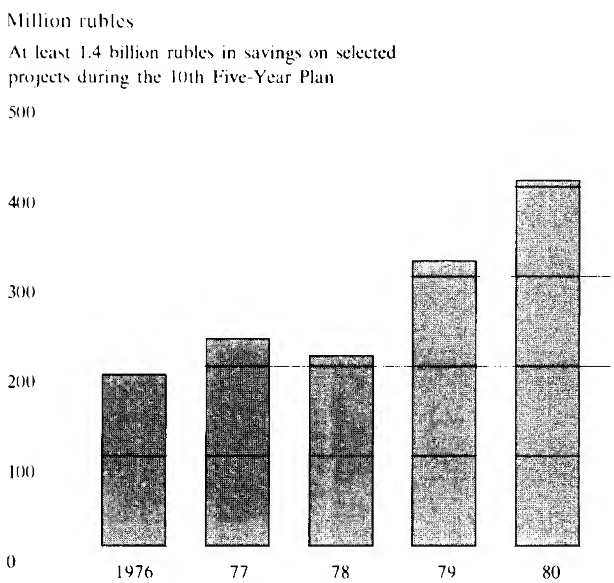
device, technologically advanced by Western standards, into a useful piece of militarily applicable hardware producible in large quantities.

The profile of the VPK program (as well as the trade diversion program) can be used to better define militarily critical technologies as well as better ways to counter Western losses. Both appear principally aimed at acquiring products and technical data. Both show that protecting dual-use products is just as important as protecting the related design know-how. Equipment sales divorced from the transfer of know-how do have long-term significance for the Soviets. The evidence indicates that equipment transfers, both large batch acquisitions and individual samples used for copying embodied design concepts and for reverse-engineering, generally outstrip acquisitions of "technology" in quantity and are of more immediate value to the Soviets.

VPK Collectors and Sources

Analysis of reliable data indicates that in the VPK program the Soviet Bloc intelligence services (the Soviet Committee for State Security (KGB), the Chief Intelligence Directorate of the Soviet General Staff (GRU), and their surrogates among the East European intelligence services) are the collectors most often tasked and the most successful.

Figure 5
Ruble Savings From Only a Part of Soviet Western Technology Acquisitions



The above savings generally are conservative estimates by the Soviets resulting from the elimination of stages of military research and design projects, the reduction in time to carry them out, and the adoption of new technical approaches. The savings are not cumulative. That is, a 20-million-ruble annual saving from the acquisition of US and other Western fiberglass plastics production technology used in manufacturing high-pressure air tanks for submarines was counted for one year only, the year of acquisition.

Roughly 400 million rubles ($640 million) were saved in 1980 for only a portion of the Western technology acquired. Most of these savings were in long-term military research projects for weapons of the late 1980s and early 1990s. They therefore were most likely given in terms of manpower savings. By this measure several tens of thousands of Soviet man-years of scientific research effort were saved in 1980.

During the late 1970s and early 1980s the Soviet intelligence services acquired, through their own efforts and those of the surrogate East Europeans, about 60 to 70 percent of all materials collected in the overall VPK program each year (figure 7). More important, these intelligence services were involved in collecting worldwide about 90 percent of the information judged by Moscow as most significant and used

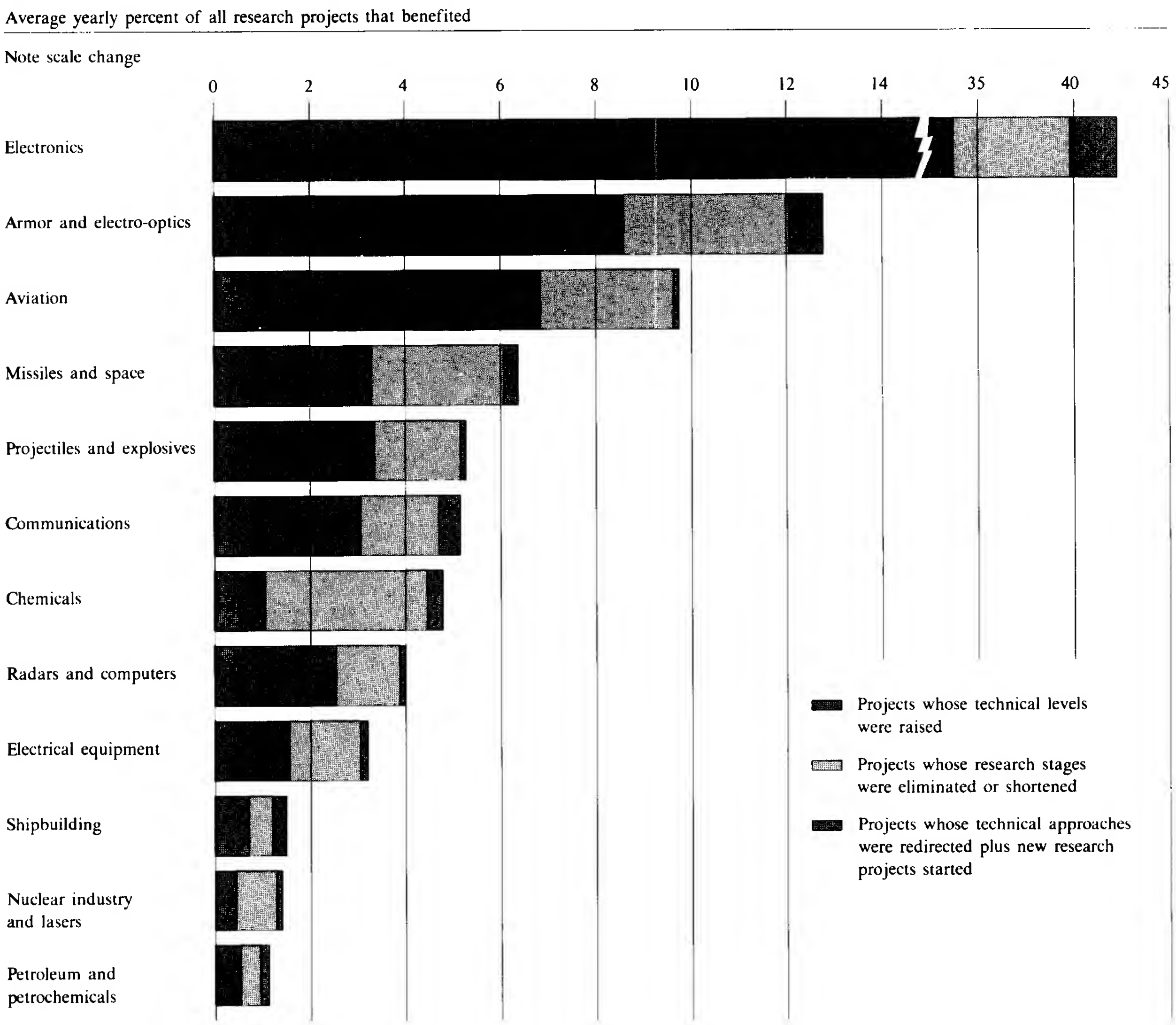
Microelectronics Reverse-Engineering

Soviet collectors have easily acquired many types of Western integrated circuits (ICs) for reverse engineering. Indeed, most Soviet ICs can be traced to a Western original. One of the best examples is their KR580IK80A microprocessor, which is a modified version of the Intel Corporation 8080A 8-bit microprocessor used in many US military systems. In this case, the Soviets even copied the equivalent US part number to avoid confusion (note the KR5 80 IK 80A versus the US 8080A).

Furthermore, the evidence clearly shows that Soviet ICs known as LOGIKA-2 and series 133/155 were directly copied from the Texas Instruments 5400/7400 family. These ICs have been used in Soviet strategic and tactical military systems since the mid-1970s to provide important qualitative improvements. The more advanced Western fabrication equipment acquired by the Soviets in recent years has been used to produce copies of sophisticated Western ICs for their latest generation of weapons. If the Soviets succeed in acquiring the next generation of materials, equipment, and parts, their military capabilities will continue to improve in the area that is the major strength of the West—quality.

The USSR's practice of reverse-engineering, however, may soon run into problems. As US and Japanese ICs become more complex, reverse-engineering will require: (a) tracking hundreds of thousands of connections; (b) understanding how they all fit together; and (c) mastering the complex processing steps used in production. Thus, copying such circuits will require not only much more sophisticated Western equipment but also much more time to duplicate each circuit, causing their overall microelectronics gap with the West to widen.

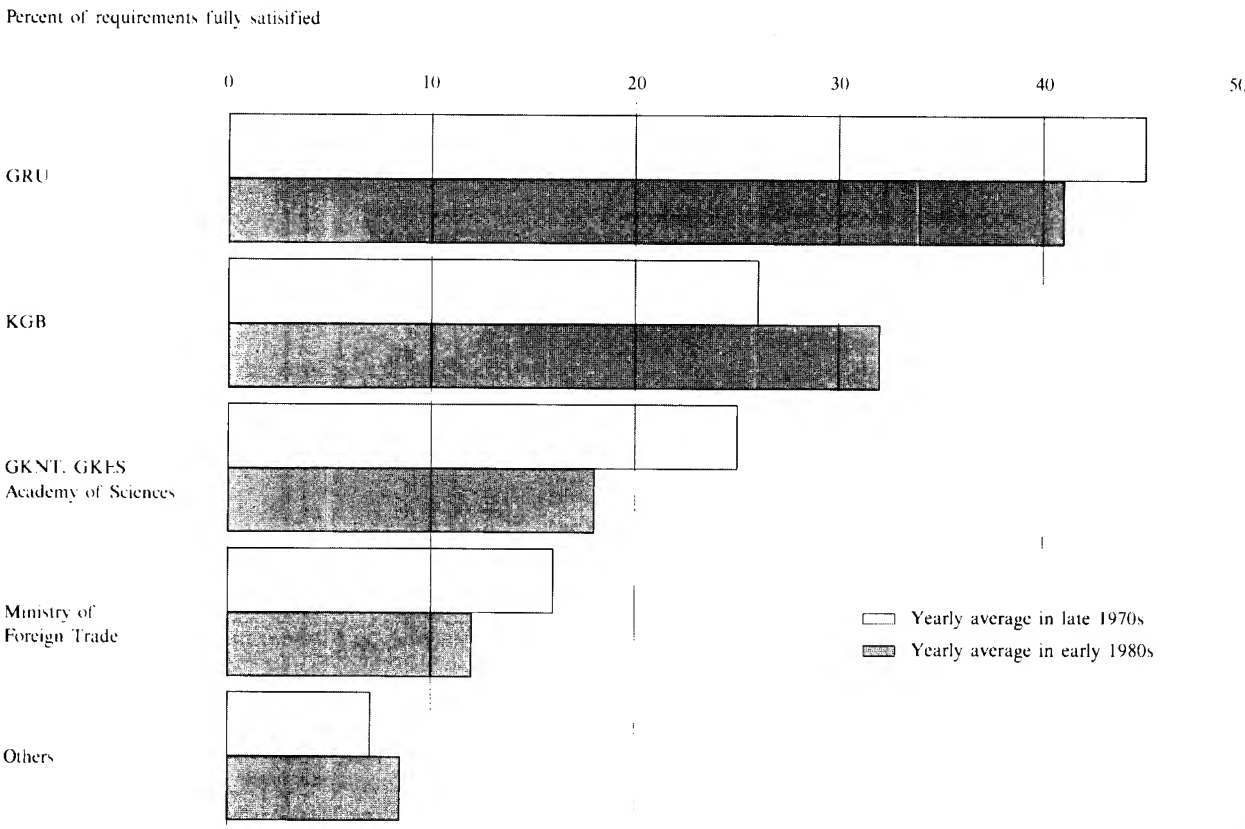
Figure 6
Rank Ordering of Industries by Soviet Military Research Projects Benefiting From Western Technology, Early 1980s



The assimilation of Western technology into Soviet industries conducting military research is considerable. The greatest beneficiaries were the electronics and armor and electro-optics industries, which accounted for over 50 percent (equaling thousands) of all military research projects benefiting from Western technology in the early 1980s.

The general distribution points out the rather broad effect that Western documents and hardware have just on raising the technical levels of Soviet military research. This is particularly true for the top three industries, where advanced technology and innovative design concepts play a significant role in weapon developments.

Figure 7
Soviet Military Requirements Satisfied by Principal Collection Agencies in the Overall VPK Program, Late 1970s and Early 1980s



The distribution shows that the KGB and the GRU (and their surrogates among the East European intelligence services) were the main collectors in the *overall* VPK program. They were involved in satisfying roughly 60 to 70 percent of all VPK requirements completely fulfilled during the late 1970s and early 1980s. (Percentages do not add to 100 because several agencies contributed to fulfilling some of the same requirements.)

Although not evident from the above data, both the KGB and the GRU significantly increased their efforts in the early 1980s because the average *number* of requirements fulfilled so far in the early 1980s (11th Five-Year Plan) increased about 50 percent over the late 1970s.

The State Committee for Science and Technology (GKNT) and associated collectors surprisingly were the third main collecting entity, satisfying a relatively large percentage. Figure 8 shows, however, that they were credited with satisfying about 5 percent of a selected subset of acquisitions, those judged by the Soviets to be the most significant to their military research projects.

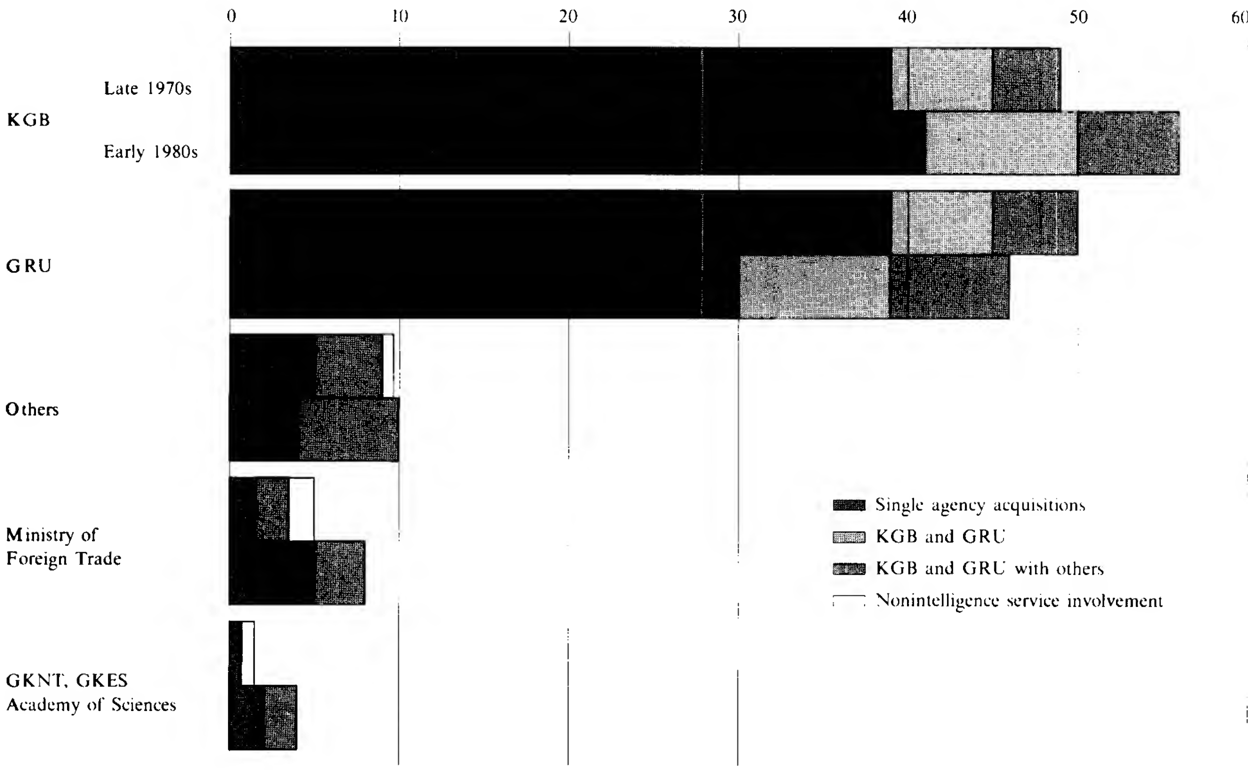
in many hundreds of military research projects (figure 8). Both the KGB and the GRU levy some of the VPK requirements on surrogates among the East European counterpart services. The KGB probably owes a higher percentage of its collection to these East European civilian intelligence services than does the GRU to its East European counterparts. All use human assets worldwide.

Coordination with the East European services is conducted through the liaison functions at both KGB and GRU headquarters as well as through KGB and GRU advisers in the various Warsaw Pact intelligence services. Since the mid-to-late 1970s the surrogates

Figure 8
Most Significant Acquisitions Satisfied by Principal Collection Agencies, Late 1970s and Early 1980s

The KGB and GRU were involved in collecting about 90 percent of the Western acquisitions judged by the Soviets to be the most beneficial to their military development projects (late 1970s and early 1980s.)

Average yearly percent of acquisitions judged by the Soviets to be the most significant



In contrast to figure 7, which shows results for the *overall* VPK program, this figure shows the main collection agencies for a selected subset of acquisitions—those judged by the Soviets to be the most significant to their military research projects for the periods indicated. The Soviet intelligence services and surrogates are the key collectors in the VPK program. Their approximate 90-percent association with the most significant acquisitions (100 percent less the percentages from the categories labeled "nonintelligence service involvement" and nonintelligence "single agency acquisitions") indicates the West has a counterintelligence and industrial security challenge.

About 60 percent of the acquisitions were of US origin (but not necessarily acquired in the United States). The several hundred acquisitions for each period in the statistics above are a small subset of those acquisitions shown in the statistics for the overall VPK program.

among these services have played a major role in the overall VPK collection program, often in return for Soviet economic concessions to their countries. The intelligence services of East Germany, Poland, and Hungary are among the most successful in acquiring Western classified data and export controlled products.

During the late 1970s and early 1980s the GRU probably fulfilled two to 10 times as many VPK requirements as the KGB for the important defense-industrial ministries of:

- Communications Equipment Industry (defense and satellite communications systems)—10 times.
- Machine Building (projectiles and explosives)—five times.
- General Machine Building (strategic missiles and space vehicles)—five times.
- Medium Machine Building (nuclear industry and lasers)—two times.
- Radio Industry (radars and large-scale computers)—two times.

The GRU probably is more successful because of its overall scientific orientation, its bolder operational style, its increased collection opportunities that reflect a wider variety of technology-related cover positions overseas, and its clearer understanding of collection objectives.

The KGB. The First Chief Directorate (foreign intelligence) of the KGB conducts science and technology collection operations through its headquarters component known as Directorate T. Directorate T probably has approximately 1,000 officers, with nearly 300 on foreign assignment. The officers on foreign assignment are organized into components known as Line X, and most of them are scientific specialists by both academic and professional training. The largest KGB complements are probably in Bonn, Cologne, London, New York, Tokyo, and Vienna. (Paris was one of the largest until mass expulsions in 1983.)

Line X officers abroad typically occupy such cover positions as science attaches in a Soviet embassy or equivalent positions in the commercial or economic sections of Soviet missions or an international organization. Other preferred cover positions for these officers are as officials in various Soviet trade missions or as members of scientific or other academic exchanges. Such positions provide easy access to the types of information targeted by the VPK or to foreign personnel who could provide such access. Cover as an "acceptance engineer" at a company with a Soviet contract is also a preferred way to acquire proprietary secrets.

The GRU. The Chief Intelligence Directorate of the Soviet General Staff has emphasized the collection of military scientific data since the earliest days of Soviet military intelligence. Unlike the KGB, the GRU has no headquarters component specifically charged with managing scientific collections; rather, this function is part of the overall responsibilities of four geographic operational directorates. GRU headquarters does, however, have a scientific information analytical directorate that supports scientific collection efforts.

The GRU does not have a separate cadre of career scientific specialists in the field; instead, most GRU officers have technical backgrounds and education as well as years in a military specialization. Approximately 1,500 GRU officers serve outside the USSR. For all of them, scientific collection is an integral part of their responsibilities and a high priority.

The GRU probably has a higher percentage than the KGB of officers with cover positions that provide more access to Western scientific targets and more methods of transporting export controlled products and technical data to the Soviet Union. Some of these positions similar to those of the KGB's scientific specialists are in scientific or commercial sections of Soviet missions or international organizations and various foreign trade offices. In addition, the GRU officers often have positions in Aeroflot (the Soviet airline) and Morflot (the Soviet merchant marine). All Soviet military attaches are GRU officers, of course. The GRU, however, does not seem to use cover positions in academic and technical exchanges to the same extent as does the KGB.

Selected Sources.

US Defense Contractors. Moscow views US and Allied defense contractors with their proprietary and government security controls as difficult targets. Accordingly, the KGB, the GRU, and their surrogates among the East Europeans are the collectors primarily tasked to operate against them. Of the top 100 US defense contractors for 1983, nine of the 10 most frequently cited by the Soviets as sources of needed technology were in the aerospace industry (table 3). The next group most frequently identified was the chemical and petrochemicals industries.

Although the Soviet Bloc intelligence services are the primary collectors of scientific and technological information in the VPK program, it is estimated that about 90 percent of the roughly 100,000 documents acquired each year worldwide are unclassified. About 10 to 20 percent of these unclassified documents are either under proprietary corporate, export, or other government controls. The Soviet intelligence services and their surrogates among the East European services probably provide Moscow with about 10,000 technology-transfer-related classified documents each year from the West. Analysis and operational observations indicate that only a small percentage of these are collected through Soviet intelligence service operations in the United States.

Analysis of hostile intelligence activities indicate that in recent years the surrogates among the East European intelligence services possibly have been more successful than Soviet intelligence against priority defense technologies in the United States. East European services have had considerable success not only in the United States, but elsewhere because:

- They are generally perceived as a lesser threat than the Soviets.
- They often may not be perceived as operating in a surrogate role.
- In some countries, including the United States, they operate under less severe travel restrictions.
- Some, especially the Czechoslovaks and the East Germans, probably find it easier to operate in the West European cultural and commercial climate.

Recent examples of Soviet Bloc espionage operations against US and other Western defense contractor targets are presented in table 4.

As a result of various coproduction arrangements and contract bidding among foreign firms, the availability of much US defense contractor technology overseas in US subsidiaries and in other firms has increased. This enables Soviet Bloc intelligence to seek priority US technologies in many countries around the world.

Commercial Data Bases. Unclassified technical documents from all countries—including engineering analyses and research results—are targeted by Soviet intelligence and other collectors because of their value to Soviet engineers seeking creative designs and alternative engineering approaches. For example, from the mid-1970s to the early 1980s, NASA documents and NASA-funded contractor studies provided the Soviets with their most important source of unclassified material in the aerospace area. Soviet interests in NASA activities focused on virtually all aspects of the space shuttle. Documents acquired dealt with airframe designs (including computer programs on design analysis), materials, flight computer systems, and propulsion systems. This information allowed Soviet military industries to save years of scientific research and testing time as well as millions of rubles as they developed their own very similar space shuttle vehicle.

The individual abstracts or references in government and commercial data bases are unclassified, but some of the information, taken in the aggregate, may reveal sensitive information concerning US strategic capabilities and vulnerabilities. Numerous unclassified US Department of Defense and contractor documents are sought by the Soviets from the Commerce Department's National Technical Information Service. Documents dealing with design, evaluation, and testing of US weapon systems—the Sidewinder air-to-air missile, the F-15, the Redeye shoulder-fired antiaircraft missile, the B-52, and others—are in the data base.

The public and private document clearinghouses—established to efficiently index and disseminate the results of government and government-sponsored military-related technical research—are a fertile ground for KGB, GRU, and other collectors. In recent years, the growing use of electronic data bases has provided the Soviets with an even more efficient means of identifying and procuring such unclassified technical information needed by Soviet designers.

Table 3
Rank Ordering of Top 100 US Defense Contractors of 1983 Compared With Their Rank Ordering by Approximate Frequency of Soviet Identification for Needed Technology, Selected Periods in Late 1970s and Early 1980s

Dollar Value Rank	Company	Soviet Identification Rank	Dollar Value Rank	Company	Soviet Identification Rank
1.	General Dynamics	8	40.	Soberbio	. . .
2.	McDonnell Douglas	5	41.	Pan American World Airways	32
3.	Rockwell International	4	42.	Harris	32
4.	General Electric	1	43.	Todd Shipyard	. . .
5.	Boeing	2	44.	Eaton	31
6.	Lockheed	3	45.	Goodyear Tire & Rubber (Goodyear Aerospace)	17
7.	United Technologies (Pratt & Whitney)	11			
8.	Tenneco	31	46.	Guam Oil & Refining	. . .
9.	Hughes Aircraft	15	47.	Atlantic Richfield (ARCO)	31
10.	Raytheon	23	48.	Sanders Assoc.	32
11.	Grumman	21	49.	Waterman Marine	. . .
12.	Martin Marietta	7	50.	Signal Co. (Garrett)	19
13.	Litton Industries	20	51.	Royal Dutch Shell Group	23
14.	Westinghouse Electric	6	52.	Motorola	25
15.	IBM	19	53.	North American Philips (Magnavox)	27
16.	LTV	24	54.	E Systems	. . .
17.	FMC	30	55.	Hercules	24
18.	RCA	27	56.	Morrison Knudsen	. . .
19.	TRW	26	57.	Mobil	29
20.	Sperry	17	58.	Ogden	. . .
21.	Honeywell	12	59.	Morton Thiokol	19
22.	Ford Motor (Ford Aerospace)	22	60.	Gould	32
23.	General Motors	14	61.	Congoleum	. . .
24.	AT&T	. . .[a]	62.	Caterpillar Tractor	25
25.	EXXON	28	63.	Emerson Electric	30
26.	Northrop	19	64.	Control Data	30
27.	Allied (Bendix)	9	65.	Standard Oil of Indiana	30
28.	Maersk Line Ltd	. . .	66.	Coastal	. . .
29.	AVCO	16	67.	Penn Central	. . .
30.	GTE	32	68.	Aerospace	24
31.	Textron	32	69.	Fairchild Industries	25
32.	Singer	23	70.	HBH (Hughes Air/Bendix/Holmes)	. . .
33.	Texas Instruments	16	71.	MIT	13
34.	Hughes Helicopters	. . .	72.	Burroughs	24
35.	General Tire & Rubber (Aerojet)	15	73.	Pacific Resources	. . .
36.	ITT	31	74.	Johns Hopkins University	32
37.	Standard Oil of California	30	75.	Oshkosh Truck	. . .
38.	Teledyne	27	76.	Gulf Oil	30
39.	Motor Oil Hellas	. . .	77.	Ashland Oil	31

[a] An ellipsis indicates that no targeting for specific technology or hardware was noted during the sampling period to rank these companies; this is not a complete indication that there was no hostile targeting of those companies. Other companies not among the top 100 are known to have been identified by the Soviets for needed technology.

Table 3 (continued)

Dollar Value Rank	Company	Soviet Identification Rank	Dollar Value Rank	Company	Soviet Identification Rank
78.	Mitre	...	90.	Gulf States Oil & Refining	18
79.	Rolls Royce Ltd.	30	91.	SAI	...
80.	Du Pont	10	92.	Sunstrand	...
81.	Williams International	32	93.	Kaman	...
82.	Reynolds Industry	29	94.	Kuwait Petroleum	...
83.	Duchossois Thrall Group (Chamberlain)	29	95.	Harsco	...
84.	NI Industry (Norris)	...	96.	Lear Siegler	30
85.	Sam Whan	...	97.	Varian Associates	29
86.	Computer Science	...	98.	Southern Union	...
87.	Xerox	...	99.	Cubic	32
88.	Brunswick	30	100.	Digital Equipment	29
89.	Hewlett Packard	27			

In the VPK program the Soviets issue general guidance to collectors to acquire selected information on, for example, a system (the US Space Shuttle) or a subsystem/technology (electro-optical guidance techniques of the US Maverick or TOW missiles). They follow up this guidance with specific "requirements" and allocate funds for particular pieces of hardware (MK 46 torpedo: more than 1,250,000 rubles (more than $3.5 million), or a U-2 aircraft radio: more than 50,000 rubles), or a document (K-250K-D gyroscope: more than 20,000 rubles), or a dual-use product (excimer laser: more than 20,000 rubles). The government agencies, companies, or contractors that have such information or products are specified. The rank ordering in this table is representative of the number of times a company was specifically identified as a source of needed information and hardware during a selected period. Duplicate numbers beginning with Soviet rank 15 indicate ties in the number of times identified. The data available give a rough indication of large Soviet ongoing needs for innovation in specific aerospace design concepts and hardware as well as for chemical technology and manufacturing equipment.

One solution appears to be to thoroughly screen all candidate data base entries and keep sensitive government information out of the public data bases or limit its availability to US and Allied defense contractors. Unfortunately, this may also inhibit the United States' own national research effort by restricting the ready availability of such information.

Scientific Conferences. Collection of information from professional and academic conferences on applied science and technology has also contributed to the success of the Soviet program. At least 35 conferences worldwide were identified in the VPK program as potential sources of specific data in the late 1970s to assist in solving military research problems. These included conferences on materials, missiles, engines, lasers, computers, marine technology, space, microelectronics, chemical engineering, radars, armaments, and optical communications. The Soviets judged some of the data acquired from these conferences to be among the most significant contributing to their military projects. Conferences in the late 1970s and early 1980s (and Soviet evaluation of the data) ranked in order of significance were the:

- International Radar Conference (improved circuit designs for synthetic aperture satellite radars and aircraft over-the-horizon radars)—Collector: GRU.

- Conference on Integrated Optics (assisted in identifying ways to produce a qualitatively new Soviet category of integrated optical devices for fiber-optics communications)—Collector: KGB.

Table 4
Selected Successful Soviet Bloc Espionage Operations Against US and Other Western Defense Contractor Targets

Agent	Hostile Service	Dates Operated	Access	Impact
William Bell	SB Poland	1978-81	US citizen. Radar specialist, Hughes Aircraft Company. Worked on advanced US radar systems, experimental radar systems, and air-to-air and surface-to-air missiles.	Saved the Soviets several tens of millions of rubles in research efforts; advanced Soviet technology by about five years by permitting them to implement proven design concepts.
Pierre Bourdiol	KGB	1973-83	French engineer.	Currently undergoing trial.
Dieter Gerhardt	GRU	1964-83	South African naval officer who had attended the British Royal Navy College and served at the Embassy in London. Later was a scientific research staff officer.	Passed information on various antiaircraft missiles.
James Harper	SB Poland	1971-81	US citizen. Electronics engineer. Through his girlfriend/wife he had access to Ballistic Missile Defense Advanced Technology Center contracts at Systems Control Inc., California.	Provided dozens of documents on potential US ballistic missile defense programs, ICBM basing modes, and related technology. Afforded Soviets a unique look at potential US future systems concepts.
Manfred Rotsch	KGB	1967-84	West German. Head of the Planning Department of the aviation firm Messerschmitt-Bolkow-Blohm (MBB).	Passed information on the "Tornado" aircraft produced by the European Panavia consortium.

- Conference of the Aerospace and Electronic Systems Society of IEEE (helped technical solutions to existing problems and improved the characteristics of a low-altitude target detection radar)—Collector: KGB.

- International Conference on Radar (assisted development of signal processing for passive jamming suppression methods and for radars to detect distant aircraft targets)—Collector: GRU.

- International Conference on Nontraditional Energy Transformation Systems (refined directions of research on space-based nuclear reactors)—Collector: KGB.

- Conference on Millimetric and Submillimetric Equipment (assisted in design solutions for millimeter wave proximity fuzes)—Collector: KGB.

- Symposium on Solar Energy Conversion (increased efficiency and decreased costs for electron beam deposition of coatings on solar components for space vehicles)—Collector: GRU.

According to Soviet estimates, the information obtained by the KGB and GRU from these conferences alone, particularly the first three, produced savings of millions of rubles in long-range military research projects—savings roughly equivalent to 100 man-years of effort. The fact that numerous professional and scientific conferences are specifically identified as valuable sources in advance by the VPK indicates their exploitation is not fortuitous, but carefully planned.

Ministry of Foreign Trade. The Soviet Ministry of Foreign Trade administers and operates hundreds of foreign trade organizations and firms around the world. This global presence and the ministry's official duties related to technology and transportation make it a practical cover organization for hundreds of KGB and GRU officers involved in technology acquisition efforts. These officers conduct overt and covert collection operations and channel the results through their respective intelligence organizations for accountability in the VPK system.

In addition to providing cover for intelligence officers, the Ministry of Foreign Trade is also a major independent collector in the VPK program and attempts to pursue most of its assigned VPK requirements on an overt basis. During the late 1970s and early 1980s, it helped fulfill about 15 percent of all fully satisfied VPK requirements (figure 7). More important, it fulfilled 9 percent of those satisfied requirements identified as "most critical." Also during that period its role was specialized, focusing largely on the acquisition of microelectronics manufacturing equipment and communications dual-use products. In view of this, it is not surprising that throughout the 10th and thus far in the 11th Five-Year Plans the Ministry of Foreign Trade was assigned to collect the largest percentage of samples (a yearly average of approximately 30 percent) as opposed to documents. The ministry also has a major role in the illegal trade activities discussed later in this report.

Overt and Academic-Related Collectors. The Soviet Academy of Sciences is another collector in the VPK program. So too are the State Committee for Science and Technology (GKNT) and the State Committee for Foreign Economic Relations (GKES). Although these organizations are involved principally in overt collection of information for nondefense industries, they also are involved in worldwide overt collection of information and technical data in response to specific VPK tasking for military research projects. Sometimes they are tasked jointly with the KGB and other collectors to satisfy these requirements.

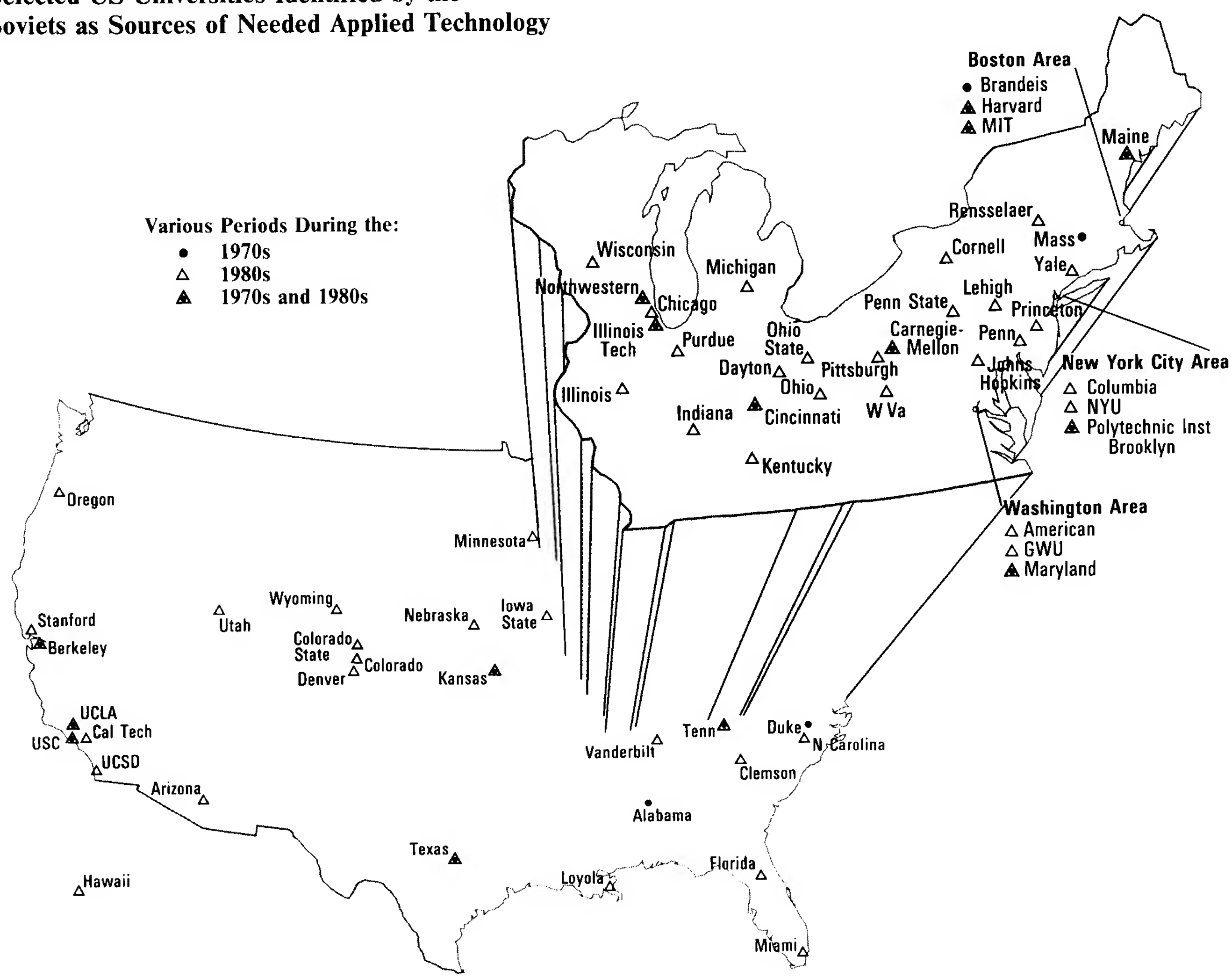
These three collection agencies, especially the Academy of Sciences and the GKNT, operate in the West in a milieu of scientific, academic, and business conferences. They and others help send approximately 2,000 Soviet Bloc citizens to the United States each year in a nontourist status. A portion of those visiting probably respond to high-priority VPK requirements. Additionally, many Soviet scientific personnel have been co-opted to some degree by the Soviet intelligence services to provide assistance to VPK and other collection activities.

During the late 1970s and early 1980s, Soviet scientific collection directives identified numerous universities worldwide that had needed information. Perhaps as a vote of confidence in US academic research, the number of US academic centers targeted has increased from about 20 to over 60 during this period. The universities cited as sources for both applied military-related technology and for civilian scientific data include some of the finest in the United States (figures 9 and 10). The majority of information sought at universities for the VPK program was applied technology and engineering, and not fundamental or basic research.

Carnegie-Mellon, Cincinnati, Kentucky, Massachusetts Institute of Technology (MIT), Michigan, and Wisconsin were among those universities (as well as defense contractors) identified in the VPK program as sources for information on new high-strength, high-temperature alloys, such as titanium, on lightweight structural alloys, and on powder metal processing. California Institute of Technology, Harvard, and MIT were targeted for techniques, methodologies, and results for evaluation of strategic concepts on space, aviation, and missile systems. California Institute of Technology and MIT were also cited as sources for transonic, supersonic, and hypersonic aerodynamic research, as were the Polytechnic Institute of New York (Brooklyn), Princeton, and Stanford. Kansas, MIT, Ohio State, and Penn State were identified for data relating to electrohydraulic control systems applicable to aircraft, helicopters, and the Soviet version of the US Space Shuttle. Research applicable to future high-energy laser and particle beam weapons was sought from MIT, Denver, and Princeton.

As illustrated in figure 7, the three overt and academic-related collectors rank third in the overall VPK program, satisfying about 20 percent of those requirements that were completely fulfilled by all collectors. On the other hand, figure 8 shows that while their overall contribution to Soviet military research collection is large in volume they accounted for about 5 percent of the technology judged most significant by the Soviets during the late 1970s and early 1980s. Acquisitions included information on developing and manufacturing composite materials for missiles and space systems; automated control designs for highly

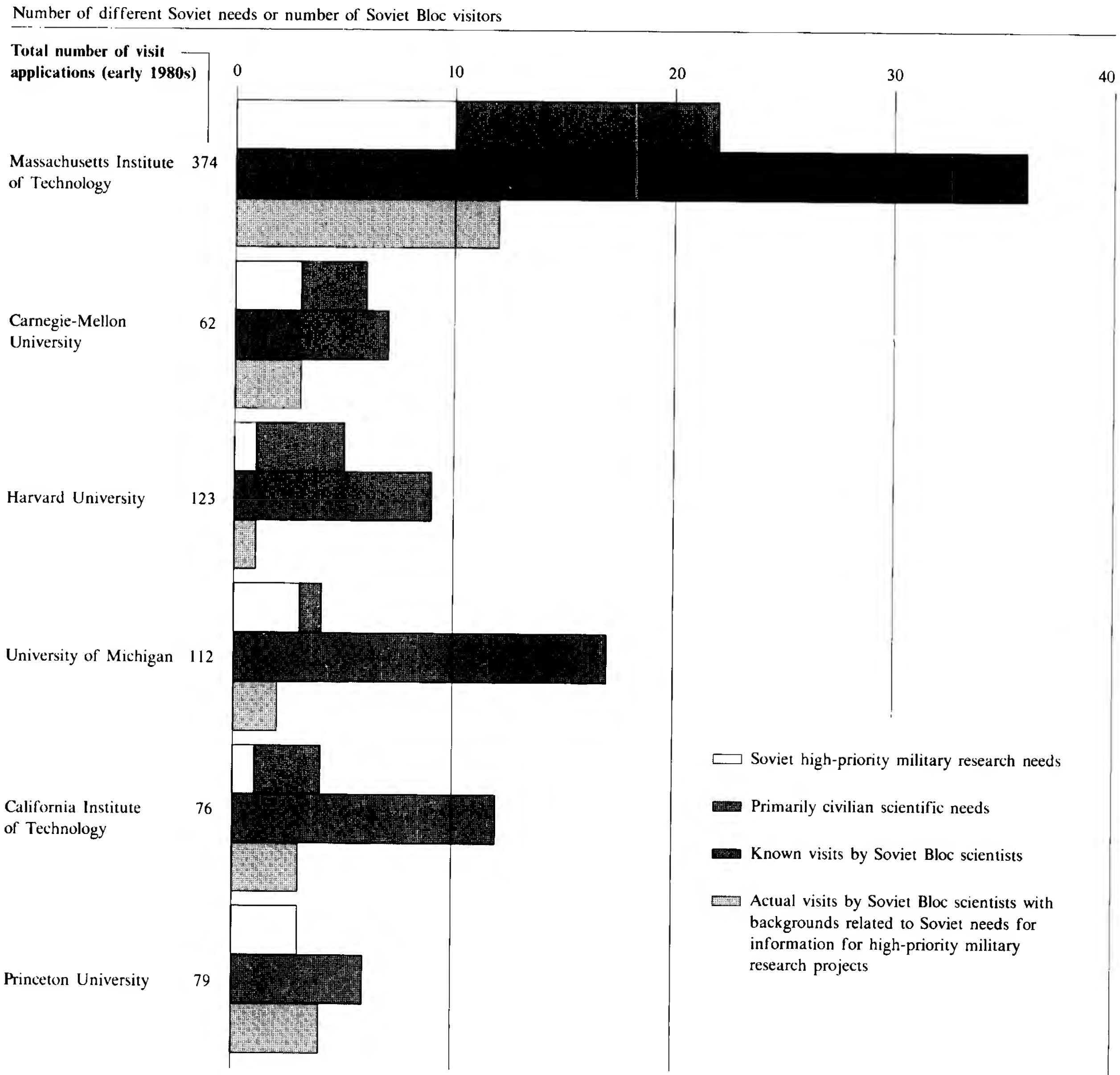
Figure 9
Selected US Universities Identified by the Soviets as Sources of Needed Applied Technology



Over the past decade or so about 40 percent of the US universities shown above were identified in the VPK program as sources of applied science and technology principally for Soviet military aerospace developments. The State Committee for Science and Technology also issues requirements against US universities, but principally for fundamental research for both Soviet military- and civilian-related science developments.

Known Soviet collectors at US and other Western universities include those from the intelligence services, scientists within the Academy of Sciences, and scientists from the State Committee for Science and Technology who come to study in the United States. Many of these collectors are also involved in spotting and assessing US scientists for potential recruitment as agents.

Figure 10
Soviet Needs for Applied Science and Technology From Selected US Universities Compared With Number of Visiting Soviet Bloc Scientists, Early 1980s



The above US universities, as well as Stanford, California at Berkeley, Cornell, and the Illinois Institute of Technology, were identified by the Soviets more often than others during the early 1980s as sources of technology needed for high-priority military and civilian research projects. There is a rough correlation between the number of VPK-identified *military* research needs and the number of visiting Soviet Bloc scientists with backgrounds related to those technical areas. There is, however, little data indicating that specific scientists were tasked to acquire information for Soviet military research projects.

accurate coordinate-measuring machines for quality control of weapon components and subassemblies; information on automatic control systems for optimizing rolling mills; acoustical data for developing low-frequency sonars for submarines; and information on aerial photography, magnetic recording systems, and lasers.

The Trade Diversion Program: Building and Expanding Industries

Numerous sources and data indicate the existence of a program separate and administratively different from the VPK program, but comparable to it in scope. This second program is characterized not by requirements for one-of-a-kind equipment, but by illegal and legal acquisitions of relatively large numbers of dual-use products for Soviet military programs. These products are requested by the defense industries for direct use in manufacturing lines to increase the throughput or output of plants or for designing future equipment. Often manufacturing cells, complete production lines, or even entire plants are sought from the West. Much of this equipment and technology falls into the areas of computers, microelectronics, numerically controlled machine tools, robotics, and material fabrication.

This second Soviet program is probably less structured than that of the VPK, but just as rigidly monitored because of the large amounts of hard currency necessary. This is the Soviet program that appears to be largely responsible for orchestrating and managing most of the worldwide trade diversions, particularly in the areas of computers and microelectronics.

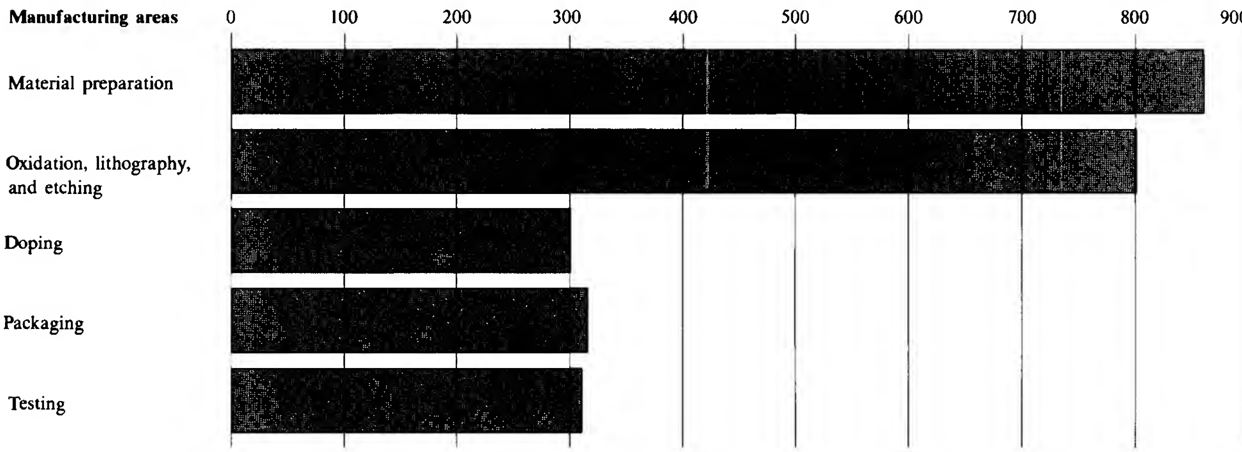
Computers and Microelectronics
Major Soviet diversion efforts are targeted at microelectronics fabrication equipment and computers; nearly half of detected trade diversions fall into these categories. Using unscrupulous Western traders who employ license falsifications, deceptive equipment descriptions, dummy firms, false end users for illegal purchases, and smuggling, as well as assistance from intelligence operations, the USSR has acquired at a minimum several thousand pieces of major microelectronics fabrication equipment during the last 10 years (figure 11). The equipment acquired through these efforts is largely responsible for the significant advances the Soviet microelectronics industry has made thus far, advances that have reduced the overall Western lead in microelectronics from 10 to 12 years in the mid-1970s to four to six years today. Western microelectronics manufacturing equipment has been applied throughout the entire production process—from materials preparation to the final testing apparatus needed for sophisticated production lines. In fact, total design and fabrication lines may have been acquired from single diversion operations.

Volume purchases, legal and illegal, characterize the second Soviet program. Examples of microelectronic products that the Soviets illegally acquired from the United States, Japan, and other countries in one year during the early 1970s include 30 sophisticated crystal pullers, 99 diffusion furnaces, three integrated circuit (IC) testers, and 10 mask aligners. The next year they diverted 24 crystal pullers, 64 diffusion furnaces, three photorepeaters, three pattern generators, three epitaxial reactors, and an IC tester. Such purchases have been used directly in assembly lines for military production. In the future, large quantities of test equipment for sophisticated very-large-scale integrated (VLSI) circuits will be a major target.

Volume purchases of materials are also part of the second program. Before 1980, the Soviets purchased hundreds of tons of electronics-grade silicon (not under export controls at that time). This is the raw material needed for integrated circuits for both military and civilian uses. The silicon originated primarily from the United States, West Germany, and Japan. After the sale of electronics-grade silicon to the USSR was restricted, Soviet acquisitions continued through worldwide diversions. Future acquisitions of silicon very likely will begin to concentrate on the very high-quality silicon produced in the United States, West Germany, and Japan for use in producing VLSI circuits.

Figure 11
Soviet Acquisitions of More Than 2,500 Pieces of Western Microelectronics Manufacturing Equipment, Early 1970s - Early 1980s

Number of major pieces of dual-use equipment



Over the past few years the Soviets have virtually completed their entire building construction program for manufacturing military microelectronics components. To equip many of these buildings with advanced production equipment, they acquired more than 2,500 pieces of major Western controlled and uncontrolled microelectronics fabrication equipment covering the entire spectrum of manufacturing operations. They acquired this equipment from the United States, Japan, and Europe, and diverted it through many parts of the world. Years of illegal acquisitions of large numbers of dual-use products through worldwide trade diversions have enabled the Soviets to narrow the microelectronics technological gap with the West from 10 to 12 years a decade ago to about four to six years today.

Integrated circuits intended for direct use in Soviet systems are usually acquired from the United States and Japan by trading companies in various parts of the world, and then shipped in huge numbers to Soviet and East European destinations. As many as 100 million circuits may be shipped in this manner every year.

In direct monetary value, volume acquisitions through illegal trade probably far exceed those of the VPK-directed effort. The Soviets have diverted thousands of different items of high technology in the past two decades, totaling perhaps billions of dollars in hardware value alone. Most of these illegal acquisitions have been facilitated or conducted autonomously by unscrupulous traders. The manufacturers of high-technology production equipment have rarely been knowingly involved in diversions; indeed, they have often been victims.

The Soviets have arranged most diversions through Europe, but their use of Asia as a diversion route is growing. Over 300 firms in more than 30 countries have been identified as engaged in diversions. Many more companies probably exist—some involved in only a few operations and quitting or disbanding before becoming well known or vulnerable.

Participants in the Second Program

The Soviet intelligence services and the Ministry of Foreign Trade are involved in various ways with most of this illegal trade, some of which is conducted through ostensibly normal trade channels. The Ministry of Foreign Trade and industrial ministries operate a large network of foreign trade organizations, commercial offices, joint companies, and foreign procurement offices whose staffs know the hardware markets

and act as ready contacts for technology traders and diverters who may volunteer their services to the Soviets. They are also quite adept at spotting opportunities for diversions and obtaining controlled Western products. These functions are performed by legitimate Soviet trade officials, intelligence officers under trade cover, and trade officials working directly for intelligence officers. Many of the 141 Soviets expelled from 25 countries during 1983 were assigned in some capacity with the Ministry of Foreign Trade.

The Soviet illegal trade program appears to be administered and managed in the trade ministry's Main Engineering and Technical Administration (GITU). Although it is a component of the ministry, GITU is staffed and managed largely by intelligence officers, organized into separate KGB and GRU groups by their respective headquarters. Its subordinate Department for Technical Cooperation with Foreign Countries is similarly staffed and managed. GITU reportedly exercises some supervision over all technical Soviet foreign trade organizations and all technical joint trading companies.

The GITU staff has grown from about 12 in 1970 to about 70 in 1983. Its subordinate Department for Technical Cooperation with Foreign Countries numbers over a hundred. The intelligence officers assigned to GITU, and to the Ministry of Foreign Trade in general, blend into a number of roles in carrying out their assignments. Soviet intelligence service personnel (as well as their East European surrogates) are in embassy commercial sections, trade missions, consulates, commercial organizations, and joint stock companies in the West. Moreover, intelligence officers have been identified as employees of foreign trade organizations in the Soviet Union and their offices elsewhere in the world.

Although GITU is largely a Soviet intelligence service domain (with the GRU probably filling most cover positions), that does not mean that all trade diversion operations are conceived of and supervised on a daily basis by intelligence officers. Some evidence indicates that the GRU is involved with more trade diversion operations than the KGB, but it is unknown if this is by design or rather a practical manifestation of the high proportion of foreign-trade-related GRU cover positions. Legitimate Soviet trade officers in Warsaw Pact countries are also involved in trade diversions, and not merely as intelligence co-optees.

Use of Diverters-for-Hire

One of the most effective and secure trade diversion methods used by the Soviets is the contract or broker diverter. Contractor diverters work for set or negotiated fees; broker diverters receive a commission, usually a percentage of the equipment purchase price. Both are individual traders or businessmen with some affiliation to high-technology manufacturing or trade circles. They are very knowledgeable of high-technology markets and product availability and either volunteer their services to the Soviets or are spotted by Soviet assets in the West or in the USSR. Some have global expertise and connections; some specialize in operations in a few countries or a few technology product lines. In some cases, the Soviets have used diverters with known track records of trading almost exclusively, or in high volume, with the East Europeans.

Whether a volunteer or selected by the Soviets, a potential contract or broker diverter is generally screened to determine the scope and depth of his contacts, range of trade abilities, and access to pertinent high-technology markets and manufacturers. In some cases such an assessment may be a rigorous one, in others perhaps only superficial. A most important quality, however, is the ability to deliver goods as scheduled, for close to the agreed prices, without complications or risks to the Soviet customer.

Although many Soviet intelligence officers are involved with negotiating and contracting with diverters, this procedure is not a classic intelligence operation and is analagous to an intelligence "recruitment" in timing only. The diverter does not accept intelligence discipline as would an "agent." Indeed it makes little or no difference to diverters if they are dealing with intelligence principals as opposed to trade officials, save for the need to avoid the suspicions of espionage. Additionally, most diverters probably do not enter into a permanent relationship with

their Soviet principals, but rather into one that is only for the duration of one or a series of formal or informal contracts for specific products or services.

Although there are dissimilarities among contract or broker diversion operations, there are some characteristics that seem consistent:

- The Soviets incur minimal, if any, risk or legal liability. Many, if not most, contracts are scheduled, briefed, signed, or verbally agreed to in Moscow or another convenient denied area or are obscured by the conduct of legitimate overt business.

- Little or no contact is maintained with the diverter. This seems especially true of diverters operating on behalf of a Soviet intelligence service.

- For the most part, the diverter has autonomy in operational decisions, including arranging front organizations, product availability, purchase, shipping, storage, and delivery. At times diverters also perform initial professional setup, testing, and servicing of equipment. In so doing they rely exclusively on professional overt and covert colleagues.

- Fees are negotiable. The Soviets will pay lucrative, but not outrageous prices. Fees can also be raised during the course of the diversion if more costs or risks are entailed by the diverter.

- Payment is generally through letter of credit deposited by the Soviets to the diverter's bank account.

The use of contract or broker trade diverter operations by the Soviets minimizes, if not obviates, the risk to their intelligence residences and trade officials while simultaneously assuring the application of professional business and trade diversion know-how to the technology acquisition task. Because of the low Soviet profile in these operations, more vigorous law and trade control enforcement may be more effective in stemming contract diversion than counterintelligence responses, although both efforts clearly have an important role.

Contract Trade Diverter: Richard Mueller

Richard Mueller, a West German citizen, is wanted in that country and in the United States for many cases involving illegal exports of COCOM-controlled computers, microelectronics, and other products to the USSR. His involvement with illegal technology acquisition on behalf of the Soviet Bloc dates back to the early 1970s. By 1978 Mueller's deals were made almost exclusively with Soviet foreign trade officials; some of these officials were intelligence officers under cover. For his network, Mueller uses numerous dummy and front firms and meets with his Soviet principals in Moscow to mask his activities. At one time he had more than 75 firms operating in Austria, France, Switzerland, the United Kingdom, the United States, and West Germany.

Between 1978 and 1983 Mueller delivered to the Soviets advanced computers, peripherals, and microelectronics manufacturing equipment worth at least several tens of millions of dollars. Perhaps Mueller's best known operation was his attempted diversion to the USSR in late 1983 of seven large US Digital Equipment Corporation VAX computers and related hardware and software. The VAX series of super minicomputers are valuable to the Soviets because of their computer-aided design (CAD) applications for microelectronics fabrication. This equipment was purchased in the United States for Mueller's dummy firms in South Africa and West Germany. Much of it was seized by Sweden and West Germany enroute to the Soviet Union.

Other Diversion Methods

Soviet foreign trade officers also attempt to make small Western firms dependent on Soviet legal orders over a period of years. For such firms, who are not contract or broker trade diverters, the occasional

Soviet request for illegal purchases or a support role in a larger illegal trade operation appears difficult if not impossible to refuse. Indeed, some firms may even be drawn into complicity or support for Soviet diversion operations unwittingly or gradually. It has long been a concern in the West to limit the expansion of Soviet foreign trade organizations abroad because of the opportunities they offer for this type of diversion activity. Although it has become more difficult for the Soviets to conduct this type of activity, Moscow continues to keep these diversion channels open.

The Soviets also acquire technology to modernize manufacturing through another mechanism, the so-called acceptance engineers. They are assigned as quality inspectors on a long-term basis, usually a year or longer, to Western firms engaged in manufacturing items for Soviet end users. These may be intelligence officers or Soviet personnel who are co-opted to steal proprietary production or technical data. They also use this opportunity for agent spotting for immediate or future exploitation. Use of acceptance engineers for collection is especially practical in countries with advanced manufacturing technology. Companies in Western Europe and in Japan have been targeted with this approach.

Prospects for Stemming Losses

The West needs to better organize to protect its military, industrial, commercial, and scientific communities, keeping two objectives clearly in view:

- First, it must seek to maintain its technological lead over the Soviets in vital design and manufacturing know-how.

- Second, it should strictly control key dual-use products, including computer-aided design and manufacturing systems, large volumes of automatic test and inspection equipment, and, most important, the automatic test equipment that can alleviate acute Soviet qualitative deficiencies in the manufacturing of weapons and military equipment.

The ultimate goal should be to deny the Soviets access to Western documents, hardware, and technologies that will accelerate their military programs and simultaneously cause Western defense efforts and costs to increase. Soviet dependence on the West for technological innovation in military research and development and in modernizing Soviet production industries is broad. It is particularly important in microelectronics and computers, and extends to key areas that include command, control, communications, and intelligence (C^3I), computer-integrated design and manufacturing, and materials fabrication (table 5).

The United States and many other Western governments have begun to better recognize that their military and dual-use equipment and technologies have been improving the performance capabilities and manufacturing standards of Soviet weapons. Several positive steps have already been taken by the United States, Western Europe, and Japan, including selective expansion of the COCOM [3] list to deny the Soviets key items. Although the emphasis has varied among countries, most have undertaken individual programs to stem diversions and losses that include some of the following:
- Increased awareness programs, highlighting the magnitude, tactics, and detriment to Western security of the Soviet efforts.
- Improved export control efforts and enhanced law enforcement capabilities.
- Counterintelligence programs specifically targeting the technology transfer activities of hostile intelligence services and their Soviet co-optees and agents.
- Industrial security awareness programs conducted jointly by counterintelligence services, security services, and corporate security professionals.
- Soviet Bloc scientific visitor controls designed to screen high security risk visitors and, in the process, strengthen the spirit and integrity of academic exchanges.
- Better review of government open publications in the prepublication or predistribution phases.

In general, a more difficult operational environment for Soviet intelligence has resulted worldwide.

[3] The Coordinating Committee (COCOM) was established in 1949 to serve as the forum for Western efforts to develop a system of strategic export controls. It is composed of the United States, the United Kingdom, Turkey, Portugal, Norway, the Netherlands, Luxembourg, Japan, Italy, Greece, France, the Federal Republic of Germany, Denmark, Canada, and Belgium.

Table 5
Examples of Dual-Use Equipment and Technology Likely To Be Targeted by the Soviets

Microelectronics

- Advanced Integrated Circuits
  - GaAs Devices
  - Memories
  - Microprocessors and Peripherals
  - Very-High-Speed Integrated Circuit (VHSIC) Devices
- Automatic Integrated Circuit and Printed Circuit Board Testers
- Chemical Vapor Deposition (CVD) Equipment, Especially Metal-Organic CVD Systems
- Computer-Aided Design (CAD) Systems
- Integrated Optics
- Ion-Beam and Plasma Etchers
- Ion-Implantation Equipment
- Lithography Equipment, Especially Electron-beam, Ion-beam, and X-ray Systems
- Molecular Beam Epitaxy (MBE) Systems
- Semiconductors
  - III-V and II-VI Compounds
  - Heteroepitaxial Materials
  - Specialized Crystal Pullers
  - Quality Silicon for Very-Large-Scale Integrated (VLSI) Circuits

Computers

- Array-Transform Processors
- Artificial Intelligence Systems
- Data Display Equipment
- High-Density Disk Storage Systems
- Internal Memories
- Software Development Systems
- Stand-Alone Mainframe Computers
- Supercomputers
- Superminicomputers

Command, Control, Communications, and Intelligence (C^3I)

- C^3I Software
- Computer Networking Systems
- Telecommunications
  - Fiber-Optics Transmission Systems
  - Digital Switching Systems
  - High-Speed Modems
  - Satellite Communications Systems
  - Terminal Displays

Computer-Integrated Design and Manufacturing

- Computer-Aided Design Software, Methods, and Equipment
- Computer-Aided Manufacturing (CAM) Software
- Computer Numerical Controls for Metalworking Machines
- Coordinate Measuring Machines
- Finite Element Analysis
- Flexible Manufacturing Systems (FMS)
- Plant Control Software
- Robotics

Material Fabrication

- Metals and Alloys
- Composites
  - High-Strength Fibers and Filaments
  - Carbon-Carbon Manufacturing
- Ceramics
- Materials Processing
  - High Temperature Resistant Coatings
  - Isostatic Presses
  - Lasers for Surface Conditioning and Material Processing
  - Material Joining and Bonding Equipment
  - Nondestructive Test and Evaluation Equipment
  - Precision Shapers and Formers
  - Vacuum Furnaces, Including Those for Single Crystal Growth

The worldwide diffusion of advanced products and high technology, however, clearly has increased Soviet collection opportunities. To take advantage of this, the Soviets can be expected to intensify operational acquisition efforts by:

- Expanding their use of contract diverters on a global basis.
- Increasing their dependence on surrogates among the East European intelligence services; increasing use of client states such as Libya, Vietnam, and North Korea.
- Increasing their exploitation of any vulnerable US and Western defense weapon system coproduction arrangements in Allied countries.
- Relying more on third-country espionage operations targeting US personnel and technology (mostly handling covert assets in areas outside the United States).
- Exploiting Third World trade entities dealing with US high technology (the Soviets contend that corporations, officials, and security services in those countries can be easily victimized).

- Attempting broader online access to US and other Western data base systems directly from the Soviet Union.

For effective countermeasures to keep pace with the evolving Soviet acquisition programs, in particular the highly effective operations of the KGB, the GRU, their surrogates among the East Europeans as well as unscrupulous traders, the West should accurately anticipate Soviet tactics. Western countries should continue to improve and modify their responses. In particular, the West needs to improve and refine its knowledge of Soviet military-technical needs and factor this knowledge into meaningful and practical, multilateral export control lists. Most important, however, must be increased multinational coordination of Western programs—for example, a systematic program among the Western customs services aimed at preventing the illegal export and diversion of militarily significant equipment in the face of what clearly will be a geographically expanding Soviet acquisition threat.

Much can be done to stem losses because much is known about Soviet efforts; it is not an insurmountable problem. But the Soviets' appetite for Western technology will continue to be voracious. They will continue to exploit any weaknesses in Western export controls, as well as policy differences among the COCOM countries, to acquire the technologies needed by their military programs for the late 1980s and beyond.

This effort is more difficult and costly for them than at any time in the past. The stakes are high and the Soviets know it; they will devote whatever resources and manpower are required to fulfill their most critical military collection requirements. The West can do no less if it is to succeed in protecting itself as well as frustrating their efforts. All in the West—governments and private industries—will need to participate.

Annex

Several Hundred Examples of Soviet Military Equipment and Weapons Benefiting From Western Technology and Products

There are hundreds of examples of Soviet military equipment and weapons of the 1980s and 1990s that have benefited or will benefit from the technologies and products of at least a dozen different Western countries. New and advanced technical directions will be incorporated into some of the weapon systems, subsystems, and equipment in each industrial area given below. The equipment in many projects will have their technical levels raised or project completion dates shortened principally because of the copying of design concepts embodied in Western technical documents, one-of-a-kind military hardware, and dual-use products.

Aviation

Four New Fighter Aircraft
New Tactical Fighter of the 1990s
A Supersonic Aircraft
Ground Attack Aircraft
Airborne Command Post
Reduced-Infrared-Signature Aircraft
Four Transport Aircraft
Reusable Space Shuttle
Air-to-Air Missile (US Phoenix-Like)
Fire-Control System for Three Fighters
Gas Turbine Engine
Ramjet Engine

Projectiles and Explosives

100-mm and 152-mm High-Explosive Shells
203-mm Artillery Shell
Sabot Design for Armor-Piercing Tank Round
Armor-Piercing Tungsten Penetrator Shell
23-mm Gun
Aviation Cluster Bomb
Remote Mining Shell Delivered by Artillery, Rockets, and Aircraft
Large Caliber Artillery Shell Casing
Small Caliber Ammunitions
Noise-Detonated Fuze
Microelectronic Radio Fuze
Millimeter-Wave Proximity Fuze
High-Efficiency Proximity Fuze for Mass Munitions
Antisubmarine Torpedo
Antisubmarine Missile
Munitions Testing Equipment
Thermal Decoy Target
Protective Blast Structure
Solid Propellant
Unmanned Target Plane Equipment

Armor and Electro-Optics

Space-Based Photoreconnaissance System
Infrared Space Reconnaissance System
Space-Based Missile Launch Detection System
Space-Based Infrared Image Processor
Synthetic Aperture Radar for Space Reconnaissance
T-55 Tank
T-64 Tank
T-64A Tank
T-64B Tank
T-72 Tank
T-80 Tank
125-mm Tank Gun
Industrial Gas Laser

Aerial Frame Camera
High-Altitude Aerial Camera
Coordinate Measuring Machine
Portable Antiaircraft Missile System
Advanced Night Vision Device
Small-Arms Night Sight
Holographic Fire-Control System
Laser-Guided Artillery Shell
Laser Gyro
Optical Computer for Tactical Ballistic Missile
Diamond Turning Device for Mirrors for Future Laser Weapons
Laser Rangefinder
Antitank Missile
Countermeasure Against US Antitank Guided Missile
Automatic Gun Barrel
New Artillery Gun Barrel
Sniper Rifle and Machinegun
High-Strength Gun Barrel from Electroslag Steel
Automated Rolling Mill for Military Production

Missiles and Space

A New ICBM
A New SLBM
Maneuvering Reentry Vehicle (MaRV)
Strategic Cruise Missile
Reusable Space System (Shuttle)
Navigation Satellites
Manned Space-Based Orbital Station
Reentry Vehicle
Carbon-Carbon Nosecone for Reentry Vehicle
Missile Motor Case Material (Based on DuPont Kevlar 49)
Surface-to-Air Missile
Missile Fuel Tank
Cryptographic System
Telemetry System

Communications

Aircraft-to-Submarine Communications System
High-Altitude Video Reconnaissance System
Video Processor for Space Reconnaissance
Reconnaissance Radio Receiver
Strategic Aircraft and Cruise Missile Communication System
Fiber-Optics Communications System
Electronic Countermeasure Station
Signals Intelligence Equipment
Narrow-Band Signal Analyzer
Cryptographic System Scrambler
Magnetic Recorder
Fiber-Optical Cable
Microcomputer for Communications
Programmable Oscilloscope
Digital Processor
Printed Circuit Board Production Equipment for Communications
Correctable Aerial Bomb
Remotely Piloted Vehicle
Electronic Page Teleprinter

Radars and Computers

ABM Radar System Design
Space-Based Oceanographic Radar
Three-Dimensional Phased-Array Radar
Over-the-Horizon Radar
Shortwave-Band Aircraft Radar
High-Capacity Computer
Disk Drives for Ryad Computer
Computer Software
BESM-6 Computer
Magnetic-Bubble Computer for Onboard Missile
Computer Matrix Processor

Nuclear and High-Energy Lasers

Nuclear Weapons Safety System
Space-Based Nuclear Reactor
Nuclear Reactors
Naval Nuclear Reactor
Water-Cooled Power Reactor
Process for Reactor-Grade Zirconium
High-Sensitivity Mass Spectrometer for Uranium Enrichment
Isotope Separation Process
Space-Based Microprocessor for a Detector
Radiation Detector
Airborne Military High-Power Carbon Dioxide (CO_2) and Carbon Monoxide (CO) Laser Weapon
High-Power Gas Dynamic Laser
Space-Based High-Energy Chemical Laser Weapon

Shipbuilding

New Aircraft Carrier Catapults for High-Performance Airplanes
New Submarine
Submarine Quieting Equipment and Techniques
Antisubmarine Torpedo
Telecontrolled Torpedo
Torpedo Missile
Laser Submarine Wake-Detection System
Radioactive Submarine Wake-Detection System
Hydrophone for Aircraft-to-Submarine Communications
Magnetometer
Surface Warship
Warship-Based Multitarget Radar Fire-Control System
Sonar System for Nuclear Submarine
Sonar for Surface Ship
Sonar for Ships and Helicopters
Sonobuoy
Radiowave Underwater Communication System for Diver-Scouts
Ship Demagnetizer
Gyrohorizoncompass for Naval Ships
Naval Gun

Electronics and Microelectronics

Photolithography System
Photomask Equipment
Microelectronics Tester (Fairchild Corporation SENTRY-7 Design)
LSI IC Circuit Mask Fabricator
Microelectronics for Onboard Weapon Systems
Large-Scale Integrated Circuit Tester
Microprocessor (Motorola MC 10800 Series Design)
16-Bit Microcomputer
Computers (Digital Equipment Corporation PDP Series Design)
Micro- and Mini-computers for Military Purposes (AM 2900, LSI-11M, PDP 11/70 and REDAC Designs and Hardware)
Memories for Onboard Radar Fire Control Systems
Computer Memories
New Semiconductor Thyristor for Military Equipment
Charge Coupled Devices
Traveling Wave Tube for Military Satellite Communications
Space-Based Laser Communication System
High-Power Microwave Tube for Onboard Radar Against Low-Flying Targets
Laser Communication, Detection, and Ranging System (Hughes Aircraft Company 3800 Design)
Infrared TV System
MIG Aircraft Centimeter Waveband Radar with Onboard Digital Processing
Compact Analog-Digital Converter
Quartz Resonator
Crystal Grower
Power Generator
Communication and Telemetry System
Microwave Generator

Chemicals	Hybrid Ramjet Engine for Cruise Missile Solid Rocket Propellant for Strategic Missile Polyethylene Production System Color Aerial Photographic Film Photographic Film for Air and Space Reconnaissance Photographic Film for Space Reconnaissance (Kodak 3414 Film) Antistatic Photoreconnaissance Film Low-Density Polyethylene Photoresist System for Microelectronic Photolithography	Polyamide Composite Materials for Aircraft and Tank Industries Carbon Fiber Production for Aerospace Applications Radiation Hardening Paint for Radio-electronic Equipment Bonding Material for Spacecraft Ion-Exchange Resins Laser Systems for Remote Chemical/Biological Reconnaissance Fillers for Deep Sea Vehicles New Gas Mask
Electrical Equipment	Space-Based Turbogenerator Tank-Mounted Infrared System Sodium-Sulfur Battery for Missiles, Space, Tanks, and Submarines Electric Step-Motors for Aviation Weapon Systems	Power Sources for Missile Installations Space-Based Solar Power Cells Spacecraft Temperature Control System Ship Electrical Supply System Batteries for Naval Ships
Petroleum and Petrochemicals	New Fuel for Strategic Cruise Missiles New Jet Engine Fuel Polyurethane Binders for Solid Rocket Fuels New Zeolite Catalyst for Motor Fuels Synthetic Motor Oil for Tanks in Arctic Areas (Mobil Oil Company) Synthetic Lubricant for Aerospace Equipment Radiation-Resistant Additives to Lubricants for Space New Lubricant-Coolant for Motor Vehicles	Rubberized Fabric Inflated Seal for Supersonic Military Aircraft Industrial Rubber for Aerospace and Armored Vehicles Industrial Rubber Seals High- and Low-Temperature Fluoroelastomer for Aerospace and Armored Vehicles Improved Protective Gear for Astronauts and Pilots Radar-Absorbing Camouflage Coating